# Resource Endowments and Economic Performance

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# Preface

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Zurich, April 2008 Christa N. Brunnschweiler

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# Introduction

Economists, political scientists and historians have long been debating the economic benefits and pitfalls of natural resources. Throughout history, there can be little doubt that resources have played a central role in the various phases of economic development. They were important for the earliest transition from hunter-gatherer to agricultural societies; for the creation and duration of the Egyptian and Roman empires; for the emergence of international trade between 1000-1500 AD, where manufactured goods from the developed centers of the early world economy – the Islamic regions and China – were exchanged against the primary goods of the periphery; and for the rise of Western Europe from the 16th century onwards, where territorial expansion was driven in large part by the desire to find new resources to exploit.[1]

Past research on the historical development phases has often focused on the importance of natural resources for the country or region seeking them – be it by trade or by conquest – and less on the countries who themselves possessed the resources. One of the earliest examples is given by the application of the "frontier thesis" to the European economic take-off starting in the 16th century. The boom in Western Europe – and particularly in the metropolitan countries – essentially began with the discovery of the New World and its vast new resource stocks. It accelerated with further exploitation of the resources in Australia, New Zealand and Southern Africa, and lasted until the resource "frontier" had been exhausted at the end of the 19th century (Webb, 1964).

[1] Refer to Barbier (2005a, 2005b: Ch.2) for a more extensive survey of historical development based on natural resources.

But frontier expansion did not only benefit the Western European colonizing countries, as Frederick Jackson Turner, the originator of the "frontier thesis", pointed out when he explained the economic development of the United States over a century ago (Turner, 1986). The consensus view is that in the "Golden Age of Resource-Based Development" from 1870-1913, many countries also profited greatly from their *own* natural resource wealth, which they managed to translate into a positive contribution to their overall economic performance.[2] For example, the economic take-off of the United States during the 19th and early 20th centuries was aided not only by the abundance of free land to feed a growing population, as mentioned by Turner, but also by the presence of rich mineral ores, coal and oil to fuel the rising industries. Similarly, during this period Canada and many Latin American countries, the Gold Coast (present-day Ghana) and South Africa, Ceylon (Sri Lanka) and Indochina benefited economically from the exploitation of their abundant natural resources, be it plantation crops or minerals (Findlay and Lundahl, 1994; Barbier, 2005a).

Two early theories were developed to explain this "Golden Age": the "vent-for-surplus theory" and the "staples theory". The first suggests that unused or "surplus" resources in the poorer regions of the world were exported and brought into productive use thanks to the post-industrial trade surge (e.g., Myint, 1958; Findlay and Lundahl, 1994). The second, closely related approach describes how the production and export of staple products set off the economic development of countries rich in land but poor in labor and capital. The rising income stemming from an expanding primary sector then generated what today would be termed spillover effects, creating investment opportunities in other sectors and eventually leading to the diversification of the entire economy. Originally launched by Innis' (1930, 1940) historical studies on the economic and social impacts of Canada's fur trade and cod fisheries, the staples theory has also been extended to help explain

[2] For more on the "Golden Age", see e.g. Green and Urquhart (1976), Schedvin (1990), and Findlay and Lundahl (2001).

the economic performance of colonial settler societies, where land – and in several cases also minerals – was abundant and the population scarce. As in the Canadian example, resource endowments (broadly interpreted to include human resources) played a powerful role in directing the early development of the colonial economies, with staple dependence giving way to balanced growth through final demand linkage.[3]

These approaches were certainly not uncontroversial, as the exchange on the staples theory spawned by Chambers and Gordon's critical article in 1966 on the effects of the early-20th century Canadian wheat boom demonstrated.[4] At that time, however, the debate was more about the extent of the positive economic effects of a boom in the primary sector (as well as about the relative merits of economic theorists and economic historians); the question of whether the exploitation of natural resources might actually have *negative* economic effects was never raised.

In more recent times however, observers have been less inclined to accept nature's bounty as an unquestionable blessing. There is now considerable debate surrounding the extent *and* the direction of the economic effects of natural resource wealth for the resource-rich countries, both regarding their historical impact since the 16th century and over the past few decades.

Some scholars have re-examined the role of natural resources, and factor endowments more generally, in the economic development of former colonies. They have linked endowments – including geographical and climatic factors, mineral resources, and native population density – to the colonization strategy chosen by the metropolitan countries, and therefore to the social and institutional structures they created, and the economic development paths

[3] Refer to Buckley (1958), Watkins (1963) and Southey (1978) for further discussion of the staples approach, and Baldwin (1956) for a theoretical explanation. See Hirschman (1958) and North (1961) for early non-Canadian applications, and Schedvin (1990) and Findlay and Lundahl (1994) for more recent examples.

[4] The exchange took place in a series of contributions by Chambers and Gordon (1966, 1967), Dales et al. (1967), and Grant (1974).

that ensued.[5] According to this new "factor endowments" approach, climates and soils conducive to growing plantation-style crops, abundant precious metal resources, and a plentiful and cheap native labor force, tended to lead to the emergence of extractive and unequal social and economic structures, which persisted well beyond the colonies' independence. On the other hand, where factors combined to create settler instead of extractive colonies, the tendency was towards the emergence of "neo-Europes" (Canada and the United States, Australia and New Zealand), where institutions resembled those of the metropolis and ultimately favored positive long-term economic development even after independence. Several studies have applied this linear endowments-development hypothesis to the issue of explaining present-day economic performance in all former colonies (Acemoglu et al., 2001, 2002) and in the whole world (Easterly, 2007). However, it is uncertain if an approach originally designed for (former) New World colonies can be extended to explain the origins of economic development beyond the Americas.[6]

Looking at what has happened closer to our times, the experience of numerous countries exporting both fuel and non-fuel minerals during the past four decades has led many researchers to associate abundant natural resources with poor economic performance, especially in developing countries. Examples of the positive effects of resource abundance, even in the context of mineral resource bounty, certainly exist. Norway has been able to turn its oil and natural gas discoveries into economic profits, which – thanks to the government's long-term investment plans – should last well beyond the day of the last North Sea rig's dismantling. Botswana and Malaysia also owe much of their positive economic development since the 1970s to the exploitation of their natural capital, in particular mineral resources. However, a glance at the economic growth and development levels in other primary-export depen-

[5] Prominent representatives of this approach include economic historians Stanley Engerman and Kenneth Sokoloff (1997, 2000, 2002), who studied the development paths of New World economies.

[6] See Chapter 1 for a deeper investigation of this point.

dent countries specializing in plantation-type crops such as coffee or cocoa does little to dispel the impression of a negative resource effect.

This apparent paradox in recent economic history of abundant resource endowments – proxied by the primary export share of GDP – coupled with low economic performance has come to be known as the "curse" of natural resources (a term popularized by Sachs and Warner, 1995a). The reasons behind the curse have been alternatively identified as the "Dutch disease", i.e. the withering of more growth-inducing sectors due to a boom in the primary sector (e.g., Sachs and Warner, 1999); the rent-seeking behavior of politicians and resource extractors (e.g., Tornell and Lane, 1999; Torvik, 2002); the corruption of the bureaucratic system and the quality of institutions (e.g., Leite and Weidmann, 2002); and the collapse of the political system and resulting civil conflict over the control of the resource base (e.g., Collier and Hoeffler, 1998, 2005). Further explanations for low economic performance in the presence of resource abundance have been found in the under-investment in human capital in resource-rich countries with respect to others (e.g., Gylfason, 2001), and in the debt overhang caused by excessive borrowing against future returns from resource exploitation, which were then eradicated by a market slump (Manzano and Rigobon, 2001).[7] Based on these observations, some scholars and policy-makers have even gone so far as to recommend that developing countries leave their natural resources unexploited so as not to condemn their economies to long-term under-performance, a view which must certainly appear extreme to anyone familiar with positive counter-examples of resource-driven development.

A substantial body of literature has shown that resource endowments played an important economic part both in the near and more remote past. But what of their relevance for economic performance today, and even in the future? It is clear that many resources which have had a crucial impact on economic development in the past – be it positive or negative – will not

[7] Chapters 2-3 of the present study offer a more extensive examination of the resource curse.

last forever, either because of their depletion or threatened over-exploitation. However, this does not mean that natural resources are no longer necessary in today's economy; the reality is quite the opposite.

Of particular concern today for both scholars and policymakers is the supply of energy resources to satisfy the ever-growing demands of producers and consumers. The reserves of the world's main energy resources – oil, gas and coal – are not inexhaustible. Moreover, while these energy resources are fundamental for economic activities, their use has also caused – and will continue to cause – significant damage to the environment, and to the human beings living in it. Other, more plentiful and less polluting alternatives already exist, including renewable energy resources – water, wind, biomass and solar energy, to name but a few – and the more contested nuclear energy resources. There is however an ongoing discussion in academic, political and economic circles regarding the optimal energy mix, the institutional framework needed for the development and practical implementation of new energy resources, and the economic effects which their widespread adoption (or lack of it) will engender. At the very least, the issue demonstrates that natural resources are far from having lost their central role for economic development; on the contrary, they may become yet more important as some of the traditional resources are exhausted and new ones must be found.

As the title suggests, this thesis explores some of the contributions of resource endowments to economic performance. It is shaped by the three broad research areas delineated above: first, the historical importance of resources for economic performance; second, the economic effects of natural resource endowments in the more recent past; and third, the debate on the consequences of and solutions to resource depletion in the near future. More specifically, the study begins by raising the possibility of non-linear effects between colonial resource endowments – broadly conceived to include also human resources – and one important facet of economic development, namely income distribution in former colonies. This is followed by an extensive re-examination of the resource curse, which has allegedly – and probably erroneously – characterized the role of natural resources in economic performance over the past four decades in a broad sample of countries. And finally, the study is completed by an analysis of the growth effects of alternative energy resources and the importance of a proper institutional framework for their development in transition and developing countries, an issue of growing relevance at a time when demand for energy resources is burgeoning in these regions.

The overall conclusions on the role of resource endowments for economic performance to be drawn from this thesis can be summed up in a concise statement: the human element – i.e. the institutional set-up and the policies that emerge from it – is more important for determining development outcomes than the mere presence or absence of natural resources. There is no evidence of a pre-determined "curse" of natural resources; not in the distant past, nor in the last decades, and hopefully not in the future either. Rather, it is the interplay of resource endowments and the institutional and economic structures created by humans to exploit those resources that point down the development path upon which an economy – be it resource-rich or not – will embark.

## Overview

This section provides a more detailed overview of the chapters that follow. Chapter 1 explores the main determinants of inequality in former colonies. Recent research emphasizes that the distribution of income in countries is not invariant with respect to the underlying characteristics of these countries. Following seminal work on incentives faced by colonial settlers several centuries ago (Engerman and Sokoloff 1997, 2002), this study examines the impact of historical factor endowments on current economic outcomes. But whereas earlier work focused on the effects on modern income levels and the distribution of world income, the focus here is on the modern distribution of income within countries.

The main objective of this paper is to analyze the relationship between pre-colonial factor endowments (especially population density), incentives for colonizers, and the resulting patterns of inequality in former colonies. A new hypothesis is proposed, suggesting that the link between the historical native population density and inequality is best described by an inverted-U shaped relationship. It is argued that this result is connected to colonization patterns and – based on historical accounts – can be explained by the ratio of land to the indigenous population in these countries on the one hand, and by the level of (military) technology attained by the European colonizers on the other. The study shows that it is the interaction of these two factors which has proved important for the development paths of former colonies. The envisaged chain of events is a three-step process: (i) the impact of historical population density on settlement and labor allocation decisions of colonial settlers; (ii) the impact of historical economic and social structures on modern-day structures; and (iii) the impact of modern structures on the distribution of income in modern societies.

The hypothesis is developed theoretically in a conflict model describing the possible interactions between colonists and natives. It is also tested empirically, using data on population density around 1500, and the Gini index and the top quintile income share as measures of inequality. The empirical results are consistent with the theory, highlighting the curvilinear relation between native population density in pre-colonial times and modern inequality patterns. Moreover, the hypothesis proves robust to controlling for other possible factors that influenced development in former colonies, such as climate, soil quality, and mineral resources.

Chapter 2 analyzes one of the most fundamental recent debates connected to natural resources and economic development, namely whether or not natural resources have been beneficial for economic growth during the past decades. As discussed above, numerous researchers have supported the view that resource-poor countries often outperform resource-rich countries in economic growth, and have drawn the conclusion that natural resources seem to have been more of a curse than a blessing for many countries. This study re-examines two main features of the resource curse literature and finds new cross-country evidence contradicting previous findings of detrimental growth effects of natural resource wealth. The first aspect addressed here regards the measurement of natural resource abundance. Most empirical studies confirming the resource curse published over the past decade have used the Sachs and Warner measure (or a variation thereof). This measure estimates resource abundance based on the share of primary exports in national income at the beginning of the observation period. The paper presented here proposes two alternative indicators, developed by the World Bank (1997, 2005), which measure per capita mineral wealth and total natural resource wealth, respectively, and which are argued to better capture a country's natural resource abundance. The second feature that this chapter concentrates on is the importance of institutional quality in the economic growth and development process. Despite a recent resurgence of interest in the topic in general, it has received limited attention in work on growth with resource abundance.

The results of the cross-country estimations show no evidence of a negative growth effect of natural resource abundance. Using the new measures of natural resource wealth, there is instead a positive direct association with economic growth over the period 1970-2000, which is confirmed when the role of institutional quality is considered. The findings are highly significant both for aggregate natural resources and for mineral resources only, which runs contrary to most of the resource-and-growth literature. Also, the estimations do not confirm the negative effects of resource abundance through institutional quality found in several other studies. Interestingly, adding an interaction term suggests that the beneficial resource effects diminish as institutional quality increases, although the overall effects remain strongly positive. The positive results hold both in ordinary least squares (OLS) and in two-stage least squares (2SLS) estimations which consider the endogeneity of institutions, and they are robust to the inclusion of a wide range of additional control variables from the growth literature.

The empirical analysis of the resource curse is continued in Chapter 3, which closely examines the characteristics of the traditional measure of resource "abundance" and its implications for empirical work in a series of OLS, 2SLS and three-stage least squares (3SLS) estimations. As mentioned above, this measure has been calculated as the ratio of primary exports to national income (generally based on the information for a single year at the beginning of the observation period), which is more appropriately thought of as a measure of dependence (or intensity) than a measure of abundance. The denominator explicitly captures the magnitude of other activities in the economy. Consequently, the scaling exercise (dividing by the size of the economy), as well as the comparative advantage in non-resource sectors, implies that the ratio variable is not independent of economic policies and the institutions that produce them. Hence, the resource dependence ratio potentially suffers from endogeneity problems and should not be treated as an exogenous explanatory variable at all in growth regressions, but rather as the outcome of specific institutional settings.

To pursue this point, the study distinguishes between two different perspectives on institutions: the first looks at "deep and durable" characteristics of societies, such as constitutional design, which then determine a range of policy outcomes – institutional proxies and otherwise – that are more "changeable". Both the "durable constraints" and the "changeable policy outcome" interpretations of institutions are potentially relevant for the resource curse. Regarding the former, Persson and Tabellini (2003, 2004) have pioneered the notion that constitutional designs have observable consequences on economic policies, finding that both presidential regimes and majoritarian electoral rules (as opposed to parliamentarian systems and proportional representation) tend to be associated with more spending for special interests. In the context of the resource curse, one may therefore expect that sectoral lobbying for preferential treatment is more successful in presidential than in parliamentary systems. As far as the more "changeable" institutional characteristics are concerned, the consensus view in the resource curse literature seems to be that resource abundance can be a blessing for countries with high-quality institutions and a curse for countries with lower-quality institutions, and that institutional quality itself is endogenous and not invariant with respect to resource endowments.

The main results of this chapter seem to turn received wisdom upside down. First, mineral resource dependence, based on the conventional Sachs-Warner resource measure in regression analyses, is influenced both by durable and changeable institutions, even when controlling for physical resource abundance. Treating resource dependence as endogenous, it is shown that countries with certain institutional designs fail to industrialize; and failing to develop significant non-resource sectors makes them dependent on primary sector extraction. Second, within the set of constitutional variables, the form of government (presidential versus parliamentary system) is more relevant than the form of the electoral system. This is interpreted as evidence that sectoral lobbying pressure from resource firms is more relevant for policy design than electoral pressure through geographically defined constituencies. Third, and perhaps most importantly, the resource curse seems to be a red herring. Properly accounting for resource wealth implies that resources may actually be a blessing for both institutional and economic development – not a curse. Moreover, instrumenting for resource dependence implies that this variable is no longer significant in growth regressions.

Finally, Chapter 4 examines the development of renewable energy resources and their importance for economic growth, particularly in developing and transition countries. A significant obstacle in the realization of new renewable energy projects is their financing: energy projects generally demand high levels of financing, which producers in less developed economies can rarely cover on their own. However, the availability of the long-term loans needed by renewable energy technology firms is positively linked to the development of the banking system, which is not often a strong point of these economies. In addition, renewable energy projects compete against fossil fuel projects, which have a longer track record, relatively lower up-front costs, shorter lead times, and often favorable political treatment. These two factors combine to make the exploitation of renewable energy resources – which would seem to be desirable both from an economic and policymaking viewpoint – more difficult in less developed economies, an interpretation which has been confirmed by numerous energy sector practitioners.

Following this line of reasoning, the last chapter presents a multi-sector endogenous growth model of the expanding-varieties type, which explains the influence of financial intermediaries on the development of renewable energy technologies in developing and transition countries. The focus is on the development of financial intermediaries – and especially the banking sector and banks' role as evaluators of potential debtors – as a driving force in the introduction of renewable energy technologies in these countries. Greater renewable energy resource development and greater economic growth in the model come from better financial intermediation and lower information costs to banks, as well as from lower external financing needs for renewable energy entrepreneurs. Policies should therefore aim at improving financial sector performance in general and financing conditions for renewable energy firms in particular, in order to foster the development of a diversified and sustainable energy sector, and through it also contribute to long-term economic growth. The main theoretical findings are tested empirically in a series of panel data regressions for 118 non-OECD countries. The empirical results are fairly encouraging: they confirm the positive effect of financial sector and, particularly, banking sector development, as well as of power sector reforms, on the use of renewable energy technologies in developing and transition countries – especially for the newer technologies such as wind, solar, geothermal and biomass.

# Chapter 1

# Did history breed inequality? Colonial factor endowments and modern income distribution*

We explore the relation between historical population density in former colonies and modern income distribution. A theoretical model highlights the potentially opposing effects of native population density on incentives for colonists to settle in new territories. While an abundant supply of native labor is an "asset" that drives up land rents, it is also a "liability" that raises the conflict costs of acquiring the land. Conflicts for land are especially likely to emerge for intermediate native population densities. Furthermore, it is shown that the relative conflict technology of the colonists also influences their colonization strategy. Upper and lower population density bounds are derived for equilibrium outcomes with a landowning élite and a relatively poor class of workers. Results are confirmed by detailed empirical tests highlighting the curvilinear relationship between native population density and modern income inequality, as well as the importance of military technology. Results are robust to controlling for geographical and mineral factors. Upon using

* This chapter was jointly written with Matthew J. Baker (City University New York) and Erwin H. Bulte (Wageningen University and University of Tilburg).

population density as an instrument for inequality in the former colonies, we demonstrate that there is no causal relationship running from distribution to economic growth.

## 1.1 Introduction

One of the classical questions in development economics concerns the nature of the two-way relationship between income inequality and economic growth and development. The research tradition dates back to at least the 1950s (e.g., Lewis, 1954; Kuznets, 1955; Kaldor, 1956), but is still relevant today (e.g., Anand and Kanbur, 1993a,b; Persson and Tabellini, 1994; Alesina and Rodrik, 1994; Clarke, 1995; Forbes, 2000; Easterly, 2007). One of the key issues in this literature is whether inequality is a barrier to growth and development. This could be the case if inequality triggers growth-impeding redistributive policies, or if it undermines institutional quality (resulting in political instability) and negatively affects the incentives and ability of a large part of the population to invest in various forms of capital (e.g., Easterly, 2007). However, the exact nature of the relation remains a subject of debate, as there is also evidence suggesting that growth is promoted if income is concentrated in the hands of an élite with a relatively large propensity to invest (see Forbes, 2000 for recent evidence along these lines).

The debate on the relation between inequality and economic performance naturally leads to another fundamental question regarding the origins of inequality itself. Recent research emphasizes that the distribution of income in countries is not invariant with respect to underlying characteristics of these countries. In other words, inequality is an endogenous variable and jointly determined along with other macroeconomic variables of interest to economists.[1] A plausible case can be made that inequality is closely linked to the insti-

[1] For example, Bourguignon and Morrisson (1998) show that income distribution in recent decades has increasingly depended on the relative labor productivity of the agricultural sector vs. non-agricultural sectors.

tutional structure of economies. However, this in turn begs an answer on the origins of institutions. To the extent that institutional structures are persistent and evolve only slowly in response to contemporary pressures (see Glaeser et al., 2004; Bourguignon and Verdier, 2000; Acemoglu et al., 2001; Engerman and Sokoloff, 1997, 2000; and Sokoloff and Engerman, 2002; but also the discussion below), we would expect inequality to change slowly as well. If so, it may be possible to trace the roots of current inequality patterns back to factors dating from much earlier periods in human history.

In this paper we set out to explore the main determinants of inequality in former colonies. Following seminal work on incentives faced by colonial settlers several centuries ago (Engerman and Sokoloff, 1997, 2002; Sokoloff and Engerman, 2000; Acemoglu et al., 2001, 2002), we examine the impact of historical factor endowments on current economic outcomes. However, whereas earlier work focused on the effects on modern income levels and the distribution of world income, we focus on the modern distribution of income within countries. The factor endowment of particular interest to us is native population density in pre-colonial days. It has been suggested that densely populated areas were an attractive "prize" for predatory colonists, as they were relatively prosperous (and therefore offered richer spoils), and because abundant native labor would prove useful as an input in plantation agriculture, mining, and other activities. This in turn led these areas to be characterized by extractive economic and social structures (e.g. Engerman and Sokoloff, 1997, 2002; Sokoloff and Engerman, 2000; Acemoglu et al., 2002). In contrast however, one might also hypothesize that more numerous populations were most likely quite capable of defending themselves, and therefore harder to conquer and subdue. If so, the relation between native population density and historical patterns of colonization and institution-building should be curvilinear, with limited colonization and subjugation effort at both extremes of the distribution (i.e. in very thinly and very densely populated native societies). With institutional persistence, this would eventually affect contemporary social structures and institutional design, in turn influencing modern income distributions within countries.

The main objective of this paper is twofold. First and foremost, we analyze the relationship between population density in former colonies, incentives for colonizers, and resulting patterns of inequality. We also test our hypothesis against some of the other popular explanations on the origins of inequality. The chain of events that we envisage is a three-step process: (i) the impact of historical population density on settlement and labor allocation decisions of colonial settlers; (ii) the impact of historical economic and social structures on modern-day institutions; and (iii) the subsequent impact on the distribution of income in modern societies. However, for lack of information on historical social structures and institutions, we follow Acemoglu et al. (2001, 2002) and leave this link implicit in the empirical analysis. Second, we use the results of the above-mentioned analysis as the starting point for the development of a novel instrument for income inequality, and use this instrument to analyze the relation between inequality and income levels and growth. We find no causal relationship running from inequality to contemporary income levels or growth in former colonies.

To motivate our analysis, we first demonstrate that the relation between historical native population density and inequality is best described by an inverted-U shaped relationship. We link this result to colonization patterns and – based on historical accounts – argue that this finding can be explained by the ratio of land to the indigenous population in these countries on the one hand, and the level of (military) technology attained by the European colonizers on the other. It is the interaction of these two factors which proved important for the development paths of former colonies.

The paper is organized as follows. In section 1.2 we briefly summarize previous research on the colonial origins of economic development and point out an important paradox in the development pattern of former colonies. We then explain this by formulating a new hypothesis on the interaction of population density and technology, and support our view with historical evidence. Section 1.3 provides a formal model that is intended to illustrate the main economic mechanisms driving colonization and subsequent social and economic development paths. In section 1.4 we empirically test our theory for former colonies, using data on population density around 1500, as well as the Gini index and the top quintile income share from the recent UNU/ WIDER (2007) dataset as measures of inequality. The empirical results are consistent with the theory, highlighting the curvilinear relation between native population density in pre-colonial times and modern inequality patterns. Moreover, our hypothesis proves robust to controlling for other possible factors that influenced development in former colonies, such as geography and mineral abundance. Section 1.5 concludes.

## 1.2 A hypothesis of colonization patterns and inequality

### 1.2.1 Economic theories and a novel hypothesis

In a series of recent papers, Stanley Engerman and Kenneth Sokoloff (henceforth ES) proposed that the roots of modern-day wealth disparities in former colonies lie in their factor endowments at the time of colonization. They hypothesized that three factors were crucial for development: the climate and soil type; the presence of precious metals; and the density of the native population. The structural differences related to initial factor endowments then tended to persist, "not only because certain fundamental characteristics of New World economies were difficult to change, but also because government policies and other institutions tended to reproduce them" (ES 2000: 223).[2]

[2] The idea that institutions persist for a long time can be found already in Wittfogel's (1957) analysis of China, Russia and the Ottoman Empire. Further evidence supporting the view that colonial institutions and economic structures in particular have persisted is provided in Young (1994), La Porta et al. (1999), Coatsworth (1999), Mariscal and Sokoloff (2000), and North et al. (2000). Bourguignon and Verdier (2000) focus on the persistence of institutions favoring an élite.

The first factor – which we will term "geography" – determined whether the colony was suitable for growing high-value crops such as sugarcane and other plantation-type products. If this was the case, the society which emerged was generally characterized by a stark class division between the landowning, white colonist élite, and the rest of the population, both native and of African slave descent. Conversely, if the soil quality lent itself more to the production of grains and hays, which had only limited economies of scale, a more egalitarian social structure typically emerged, based on small landholdings owned and worked by white settlers.

Mineral abundance – the second factor – greatly influenced the early development of Spanish American countries such as Mexico and Peru. The Spanish authorities awarded large land-grants (*encomiendas*) to the narrow European-descent élite, often including claims to mines as well as to the native labor force residing near the estate. The main focus of the conquerors was the exploitation of the mineral resources – primarily silver and gold – and the extraction of labor and tribute from the native population; low-value "bulk" primary products such as meat remained under-exploited until the advent of cheaper transport in the 19th century (Waites, 1999).[3] Again, areas rich in mineral resources tended to generate economic structures with very unequal wealth distributions between the owners of the mines and the mine workers.

The third factor, the native population density, influenced all New World colonies in a similar fashion, and according to ES, its interaction with the other factors was crucial for determining the development patterns in the colonies (see also Ferguson, 2002). Sparsely inhabited territories encouraged settler-type colonization, based on European-descent immigrant laborers and small-scale farmers. The result was the emergence of relatively homo-

[3] The main natural resources exported from Spanish America to the Old World until the 19th century were precious metals. It is estimated that the Americas – foremost Mexico and Peru – produced about 102'000 tons of silver from the time of their discovery until 1810, equivalent to 85% of world production. Similarly, the New World also delivered around 70% of the world's gold produced during that period (Waites, 1999: 35-36).

geneous populations with similar wealth and human capital distributions. Conversely, large native populations provided abundant cheap labor to work on the colonists' estates, plantations and mines.[4] Consequently, substantial native populations at the time of colonization are linked to more unequal societies.

Though not uncontroversial, the historically-founded research of ES has inspired several recent and interesting empirical studies which have made use of their hypotheses. And although the focus of ES was on the Americas, their approach has been extended to encompass all former colonies, or even the entire world. For example, Easterly (2007) uses the ratio of soil suitability for growing wheat versus sugarcane as an instrument for inequality. He then finds that inequality predicts development, measured alternatively by present-day income levels, schooling rates, and institutional quality. Acemoglu et al. (2001) use settler mortality as an instrument for institutional quality to explain modern income levels. They find that areas with a more hospitable climate and disease environment are linked to higher levels of institutional development, and through that to higher present-day income levels. Acemoglu et al. (2002) use early native urbanization rates and population densities to explain their hypothesis of a "reversal of fortune". Because densely populated areas were more likely to be subjected to extractive institutions by European colonizers, they ended up with institutional set-ups which were less favorable to broad investment activities of the type needed to take advantage of the industrial revolution. Densely populated – and therefore rich – countries at the time of colonization consequently have lower income levels today, and vice versa.

[4] An interesting case of how the conquerors used the more numerous native population to their own advantage is given by the (forced) relocation of Tlascaltecan families into northern Mexico starting in 1580. The Tlascaltecans – Spanish allies since the days of Cortés – were intended to protect the sparse white settlers against the "rude tribes" along the borders; in return for this "service", they benefited from certain privileges such as the exemption from tribute (Bolton and Marshall, 1920: 59).

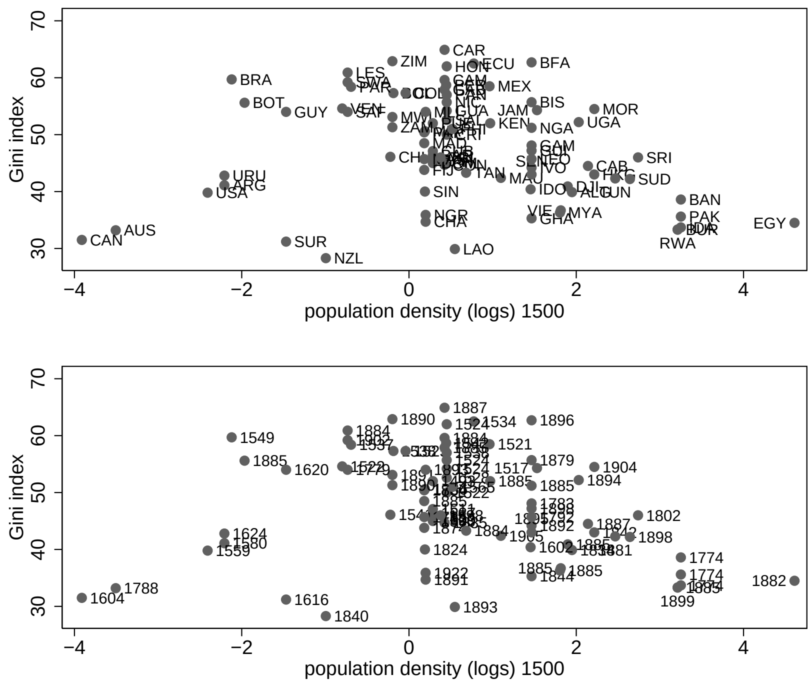


Figure 1.1: Population density in 1500 and modern inequality

*Notes*: Scatter plot of (log) population density in 1500 and inequality measured by Gini index. Figure 1.1(a) above shows results listed by country, Figure 1.1(b) below by year of colonization.

Previous studies have assumed that the relationship between economic and institutional development and early factor endowments is pretty much linear, not only for the New World colonies examined by ES, but also for colonies (and even non-colonies) elsewhere. However, this assumption turns out to be false for one fundamental factor, namely native population density at the time of colonization. Figure 1.1 plots the influence of population density in 1500 ca. (in logs) on modern inequality, measured by the Gini index around 1960, for all former colonies.[5] Clearly, the relationship is not lin-

[5] Scatter plots using the top quintile income share as the measure of inequality show the same pattern. Note that here as in the rest of the paper, we do not include those countries which were colonized for a brief period in the 20th century when colonial empires were already on the wane, such as Libya (a colony from 1911-1947) and Ethiopia (1936-1941). The data is discussed in more detail in Section 1.4.

ear, but rather roughly follows an inverted-U shape. It also appears from the years of colonization in Figure 1.1(b) that the change in colonization pattern – where population density is linked to the maximum observed inequality levels – occurred around the turn of the 18th century.[6] What determined this fundamental change in colonization patterns, which appears to have influenced economic development to this day?

We develop and test the hypothesis that European colonization, and the subsequent distribution of wealth in the colonies which has persisted until modern times, is attributable to the ratio of land to native inhabitants which the early colonizers were confronted with, and to the (military) technology of which they disposed. To state it simply: the colonizers traded off a higher native population, with the possibility of cheap labor it entailed, against the cost of military conflict and subjugation of said population. We hypothesize that (i) very low native population densities tended to lead to settler-type colonization, with more egalitarian social and political structures and hence more equal wealth distributions (as in ES); at the other end of the spectrum, (ii) very high native population densities tended to lead to the adaptation of existing social and institutional structures by the colonizers, as forced change would have been too costly. A narrow (white) élite controlled the administrative center previously held by the native ruling class, leaving the rest of the social and institutional structure largely unaltered. Depending on existing conditions, this could often imply a relatively more equal distribution of wealth. In between lie those colonies where (iii) native population density was low enough to permit conquest and control by force, and yet high enough to make cheap native labor an attractive option, creating unequal societies with a large income gap between the colonizing élite and the rest of the

[6] Two countries – South Africa and Indonesia – are listed with the dates of the official founding of the first permanent trading post in the early 17th century. In fact, though it is difficult to assign an exact date to the moment where most of the present-day area was conquered, the inland territorial expansion remained circumscribed until the 18th century.

population.[7]

### 1.2.2 Historical background

Most former colonies – with the notable exception of Australia and New Zealand, whose discovery in the late 18th century can indeed be regarded as more coincidental – were already familiar to Europeans by the end of the 17th century, either through first-hand discovery or second-hand information. They had known the countries along the North African coast of the Mediterranean for centuries, and they had heard of the sub-Saharan African civilizations and of the far-off Asian countries from exchanges with merchants and adventurers. Portuguese traders began exploring the African coast southward from the 15th century onwards. Vasco da Gama and Albuquerque rounded the Cape of Good Hope, sailed up the East African coast and and reached as far as India and Malacca at the turn of the 16th century, plundering port towns and setting up new trading posts along the way. During the same period, Columbus, Cortés and Pizarro conquered (most of) the Americas; and soon afterwards, the Spaniards established the westward route from Central America to their new Pacific colony of the Philippines. It would be difficult to contend that there was nothing to tempt conquerors into Africa or Asia, given the presence of precious metals and other coveted natural resources such as spices. Yet the vast territorial conquests in the New World during the 15th and 16th centuries were not echoed by similar advances in Africa and Asia: there was to be no more major territorial conquest until well into the 18th century (not counting the small and sparsely populated island colonies of Mauritius and the Seychelles, taken over by the French in the first half of the 18th century).

[7] Our hypothesis not only helps to explain the colonization pattern of those countries that were ultimately conquered, but may also shed light on why some countries defied colonization, most notably the densely populated and technologically advanced China and Japan. As military conquest failed repeatedly, European powers were limited to competing for their commercial positions in these countries.

In their early conquests, the Europeans' military technology had brought them a definite advantage over the native populations, which not only lacked firearms, but also had few defensible bases to fall back on. However, the relatively easy victories over the great civilizations of the Aztecs and the Incas in the Americas, and a few decades later over the Filippinos, could not readily be repeated in other parts of the world, where the obstacles facing the small groups of Europeans were more formidable (see e.g., Guilmartin, 1995; Parker, 1996). European conquest in Africa was halted by heavy native resistance and the hostile disease environment, evidenced for example during the failed Portuguese attempt to establish a colony in Luanda in the 1570s (Waites, 1999) or their abortive expedition up the Zambesi river in the 1690s (Black, 1995; Keim, 1995). In Asia, the Europeans found themselves facing opponents at roughly equal technological levels. Their main early advantage lay in the gunned sailing ship, which enabled them to terrorize coastal towns;[8] however, this technology was soon imitated and put to effective use, as the naval battles off the Malabar Coast in 1503, off Tunmen on the Chinese coast in 1522, and in the sultanate of Aceh demonstrate (Guilmartin, 1995; Parker, 1996; Waites, 1999). Moreover, the early warships carried too few troops to successfully launch amphibious attacks on the relatively heavily populated interior (Cable, 1998; Waites, 1999).

In short, in both Africa and Asia – with the exception of the Philippines – native opposition limited European territorial expansion to the occupation of coastal forts and sometimes the immediate *hinterland*.[9] Where forceful conquest proved too costly to accomplish, Europeans engaged in more peaceful activities, either farming in order to replenish the supplies of the merchant

[8] For more on the historical importance and the advances in early naval warfare, see Glete (2005).

[9] Several European powers had managed to establish footholds in Africa and Asia by the end of the 17th century. For example, the Dutch controlled Batavia (present-day Jakarta) and the small Cape Colony, as well as some coastal enclaves on Ceylon (Sri Lanka). The Portuguese were present in several port towns along the West African Coast and in Timor; and the British had made advances in some coastal areas of the Indian subcontinent.

vessels (as in the Cape Colony), or specializing in trade – mainly in gold and slaves in West Africa, and in spices and textiles in Asia. They "undertook military expenditure either to coerce reluctant buyers or in order to safeguard themselves against attack from their European rivals; the cost of defence would otherwise have eaten up all their trading profits" (Parker, 1996: 132).[10]

From the mid-18th century however, the Europeans were able to rapidly extend their colonial dominion inland into hitherto impregnable regions, starting with major advances in the Indian subcontinent and Indochina (see e.g., Parker, 1996) and culminating in the "scramble for Africa".[11] This shift in the balance of power between "the West and the rest" coincides with the completion of a remarkable series of technological innovations in Europe, which historians have called the "military revolution". The term, originally coined by Michael Roberts in 1955, encompasses the introduction of three key innovations between 1560-1660:[12] the capital ship with its broadside guns and

[10] This is the period of the rise of the great European Trading Companies, foremost the Dutch and British East India Companies. Although territorial conquest was not among their chief objectives, it gradually came as a consequence of efforts to preserve their trading positions (Waites, 1999). Where there was organized resistance, "the conqueror [negotiated] with it in order to break it all the better later" when the opportunity arose, most commonly by seeking allies among the opponent's rivals (Ferro, 1997: 32; for more on the importance of native collaboration for imperialism, see Robinson, 1972). This strategy proved effective for the British in India, the Dutch in Indonesia, and later the French in the Maghreb.

[11] This paper does not aim at exploring the reasons behind the scramble for Africa in the 19th century; for more on this subject, see e.g. Louis (1976) and Förster et al. (1988). We simply contend that population density and European technology played a role in determining colonization patterns and economic development paths in former colonies.

[12] Roberts proposed the term "military revolution" during his inaugural lecture in Belfast in 1955. His speech has been published and revised several times, most recently in Roberts (1995). The concept and timing of the military revolution is not without controversy; but most historians agree on the main innovations, and the fact that they had been adopted throughout Europe by the end of the 17th century. For more on the debate, refer to Lynn (1991), Rogers (1995), and Parker (1996).

greater sea-endurance; the development of gunpowder weapons "as the arbiter of battles and sieges"; and in response to the latter, the development of the artillery fortress or *trace italienne* (Parker, 1996: 159).[13] These innovations enabled the Europeans to overthrow – and maintain – many of those densely populated and relatively advanced areas which had previously defied conquest. A good example is given by India: the early colonial strategy of the British (at the time represented by the British East India Company) was to concentrate their trade efforts in relatively small and weak areas with few European competitors, such as Golconda, the Carnatic, and parts of Bengal. But by the end of the 18th century, with the help of native *sepoy* armies trained by Europeans and armed with European-made weapons, the British were able to successfully challenge the smaller independent states, as well as their French rivals on the subcontinent. From the rest of Bengal, they moved on to Bihar and Orissa, before their progress was halted by the Marathas, who had in the meantime adopted European military techniques. The whole of the Indian subcontinent was finally conquered in the 19th century (see e.g., Parker, 1996; Waites, 1999).

Hence, population density and technology notably influenced European colonization patterns. Following pioneering work by ES and Acemoglu and co-authors, we aim to complete the picture by drawing the link to the social and economic structures which emerged, and explain the inverse-U shaped relationship with inequality. As regards the colonies conquered before the 18th century, the Americas as well as the Philippines, our hypothesis closely follows that of ES, without further need for historical evidence. Areas with low native population densities were relatively easily conquered; they encouraged settler-type colonization and tended to produce egalitarian societies. More substantial native populations were aggressively subdued, and previ-

[13] Gunpowder weapons already came into use in the 14th century; but early firearms such as the *arquebus* were notoriously inaccurate and difficult to handle, and it wasn't until the 16th century that they gradually became more effective on land and on board ships, and as small firearms (Parker, 1996).

ous systems of labor and tribute were partly borrowed and adapted to create highly unequal "plunder economies". Where native death rates were particularly high due to disease, enslavement, or hunger, African slaves and *mestizos* provided the cheap labor force necessary to work the plantations and mines.

By the end of the 17th century, the colonizers seem to have reached the limits of the native population size which they could overthrow and extract cheap labor from by force. But as the Europeans' technological level increased, some new territories followed the pattern of the more densely populated Latin American colonies. For example, the early population densities and present-day inequality levels in Southern Africa are comparable to the more populous New World colonies such as Guyana, Cuba and Panama. However, native resistance to the early European colonists was decisive enough to delay full conquest of the southernmost part of Africa until the 18th century. But once imposed, colonial rule gave rise to similar development paths as those seen in densely populated American countries: white settler colonists competed for land, labor and influence with the native Africans. Typically, strict racial restrictions in all economic and social areas emerged, with a small number of white landowners and capitalists forming the privileged élite (Gellar, 1995).[14]

However, though central institutions may have been relatively easy to capture thanks to their technological superiority, imposing colonial authority in vast new territories with large native populations proved much more difficult. Many of the more densely populated areas of Africa and Asia not only had advanced technology levels which enabled them to put off colonial conquest, but also economic and social systems comparable with those of European countries (e.g., Parker 1996; Waites 1999). As the Europeans conquered more and more populous areas, their strategy leaned towards adapting

[14] These differences persisted and were even reinforced in the early 20th century with the Land Acts in South Africa and Rhodesia that restricted ownership of the best land to whites and sought to relegate the remaining African farmers into poorly paid dependent labor (Waites, 1999).

the native social and economic structure without imposing profound changes, leaving these colonies with relatively egalitarian income distribution patterns. There were simply too few colonists and auxiliaries for true armies of occupation, and too little money for effective policy implementation throughout the colonial societies.[15] In sum, the essential feature of European colonial rule in Africa and Asia is the conservation of the traditional social and also economic institutions, "while the administrative apex was monopolized by a white élite" (Waites, 1999: 147).

[15] In Africa, relatively populous Nigeria was not conquered until the 1880s, and administration and taxation in the colony once conquered were only possible with the support of the Muslim *Fulani* aristocracy. But in order to gain this, the British colonialists (who had allegedly espoused the humanitarian and abolitionist causes in the late 18th century) had to reach a compromise with the slave-owning *Fulani*, which meant that the traditional slave society was only phased out by the 1930s (Waites, 1999). Most of the Nigerian population was left out of the colonial economic system, which essentially precluded economic development (Gellar, 1995); these early differences seem to be reflected in modern income inequality levels, with a relatively high Gini index of 51. Uganda is an interesting example of a very densely populated colony with present-day inequality levels comparable to those of Canada and Australia. Slave raids had been frequent in this region, and European protection in the 19th century was welcomed (Waites, 1999). Rural farmers were not displaced by colonial policies, and even enjoyed some increased economic opportunities producing cash crops such as cocoa and coffee for European export. The colonial impact on the social and economic structure in Uganda was limited to the central administration by a small group of white colonists (Gellar, 1995). India had early native population densities at the upper bounds of all former colonies (25.81 per square km on average); yet its modern income inequality level is close to that of the U.S. and Uruguay (35.56 vs. 36.02 and 36.61, respectively). The British secured authority over the Indian subcontinent by a mix of aggression and collaboration with the traditional élites. When the British Government officially took over the rule of the colony from the East India Company in 1774, it adapted to and even reinforced the traditional social system. Above all in the countryside where most Indians lived (and continue to live), change was hardly evident and modernization practically wholly absent. The colonial rulers "chose security over development" as they lacked the power resources to effectively transform and develop the entire society (Waites, 1999: 184).

## 1.3 The model

In this section we build a formal model that brings out some of the main ideas that will be tested empirically below. Following earlier suggestions by ES and Acemoglu and co-authors, a key role is played by the population density of the native population. However, extending earlier work, we not only view natives as a production factor or an input in colonist-dominated production processes. We also recognize that more densely populated areas are probably better able to defend themselves.

### 1.3.1 Setting up the model

We set out to derive the equilibrium state of an economy in which "natives" and "colonists" (also called "settlers" in what follows) combine land and labor to produce an output, and in which colonists divide their time endowment between two activities: producing, and contesting land resources (i.e. engaging in conflict to fight for, and ultimately control, part of the land resource base). To facilitate the analysis, we assume that there exists a set of markets for land and labor, so that factor endowments determine relative factor prices. Colonists can either purchase or rent land on the market, or alternatively engage in conflict in an effort to "grab and control" it by force. We assume colonists use a different type of technology than natives do, possibly because they have imported certain novel skills and management ideas (e.g., European agricultural technologies, as well as new crops – both for subsistence and export – and livestock). Specifically, we assume that colonists produce using a *constant returns to scale* technology $x = s_c A_c^{\alpha} L_c^{1-\alpha}$, where $s_c$ is total factor productivity, $L$ is labor, and $A$ is total land in the "colony". The assumption of constant returns implies we do not need to keep track of land and labor use on each colonial farm or plantation, and don't need to distinguish total aggregates from individual amounts. Natives, by contrast, produce using the *diminishing returns technology* $x = s_n a^{\alpha} l^{\beta}$, where $\beta < 1 - \alpha$. One interpretation is that each native runs his own farm (or that monitoring effort in larger-scale native production structures is imperfect).

Denote the number of colonists by $n_c$, which will be endogenized below, and the number of natives by $n_n$, which will be a parameter throughout. We assume that initially the natives control the entire land base. We can solve for the amount of labor and land used in the colonist and native sectors in equilibrium. Maximization of profits is subject to the constraint that demand equals supply across all markets, as well as the resource balance conditions for labor and land ($L = L_c + n_n l_n$ and $A = A_c + n_n a_n$). The labor used on each native farm and in the colonist sector is then given by:

$$l_n^* = \left(\frac{s_n}{s_c}\right)^{\frac{1}{1-\alpha-\beta}} \left(\frac{\beta}{1-\alpha}\right)^{\frac{1-\alpha}{1-\alpha-\beta}}, \tag{1.1}$$

and

$$L_c^* = L - n_n \left(\frac{s_n}{s_c}\right)^{\frac{1}{1-\alpha-\beta}} \left(\frac{\beta}{1-\alpha}\right)^{\frac{1-\alpha}{1-\alpha-\beta}}. \tag{1.2}$$

Similarly, land use is described by:

$$a_n^* = \frac{A(1-\alpha)}{(1-\alpha-\beta)n_n + \frac{\beta L}{\left(\frac{s_i}{s_c}\right)^{\frac{1}{1-\alpha-\beta}} \left(\frac{\beta}{1-\alpha}\right)^{\frac{1-\alpha}{1-\alpha-\beta}}}}, \tag{1.3}$$

and

$$A_c^* = \frac{\beta A \left[L - n_n \left(\frac{s_i}{s_c}\right)^{\frac{1}{1-\alpha-\beta}} \left(\frac{\beta}{1-\alpha}\right)^{\frac{1-\alpha}{1-\alpha-\beta}}\right]}{(1-\alpha-\beta)n_n \left(\frac{s_i}{s_c}\right)^{\frac{1}{1-\alpha-\beta}} \left(\frac{\beta}{1-\alpha}\right)^{\frac{1-\alpha}{1-\alpha-\beta}} + \beta L}. \tag{1.4}$$

We can solve for the marginal product of land and labor by solving for the equilibrium rental and wage rates at the above allocations. This yields the following expression for the rental price of land:

$$r^* = \alpha s_c \left[\frac{(1-\alpha-\beta)n_n \left(\frac{s_i}{s_c}\right)^{\frac{1}{1-\alpha-\beta}} \left(\frac{\beta}{1-\alpha}\right)^{\frac{1-\alpha}{1-\alpha-\beta}} + \beta L}{\beta A}\right]^{1-\alpha}. \tag{1.5}$$

Solving for the rental price of labor (the equilibrium wage rate) yields:

$$w^* = (1-\alpha) s_c \left[\frac{\beta A}{(1-\alpha-\beta)n_n \left(\frac{s_i}{s_c}\right)^{\frac{1}{1-\alpha-\beta}} \left(\frac{\beta}{1-\alpha}\right)^{\frac{1-\alpha}{1-\alpha-\beta}} + \beta L}\right]^{\alpha}. \tag{1.6}$$

For simplicity, each of these can be rewritten as follows:

$$r^* = \alpha s_c \left( \frac{n_n \Psi + \beta L}{\beta A} \right)^{1-\alpha}, \tag{1.7}$$

and

$$w^* = (1-\alpha) s_c \left( \frac{\beta A}{n_n \Psi + \beta L} \right)^{\alpha}, \tag{1.8}$$

where $\Psi$ is a combination of production parameters. These expressions inform colonists about the return to production, which in turn is relevant when deciding whether to invest their effort in working, or alternatively in grabbing part of the land (i.e. engage in conflict). The solution to the colonist's problem involves comparing the returns to the two activities, where the returns to grabbing are determined by the value of land (equilibrium rental rate) multiplied by some factor describing how easy it is to seize land, and the returns to working as derived above.

Suppose that the colonists are split between $n_c^p$ colonists who choose just to work, and $n_c^r$ who allocate their effort to fighting. In what follows, we consider a decentralized scenario where individual colonists decide about the optimal allocation of their time, but a qualitatively similar story can be readily developed based on a planning model with a central colonial authority deciding about what colonists should do with their time.

To describe the land contest process, we employ a standard conflict specification in the spirit of pioneering work by Grossman and Kim (1995) and Hirschleifer (1995):

$$Y_c = \frac{\phi n_c^r}{\phi n_c^r + n_n} A, \tag{1.9}$$

where $Y_c$ is the total land base grabbed by colonists, and $\phi$ is a variable measuring the (relative) offensive strength of the colonists. From equation 1.9 it is clear that the share of land that colonists wrest from natives depends upon the relative population numbers and upon some technological advantage. In fact, however, the technological advantage may be more pro-colonist if the native population is very sparsely distributed, so population density itself matters. Following Baker (2003), this might be captured as:

$$Y_c = \frac{\phi\left(\frac{A}{n_n}\right) n_c^r}{\phi\left(\frac{A}{n_n}\right) n_c^r + n_n} A. \tag{1.10}$$

Assume that the function $\phi$ is decreasing in its only argument, but could possibly "shift" due to technical change in conflict techniques – an issue to which we return later. If there are larger amounts of natives per unit of land, it becomes, other things equal, harder to conquer native land. The amount of land captured by any individual colonist is simply $Y_c/n_c^r$, or:

$$y_c = \frac{\phi\left(\frac{A}{n_n}\right)}{\phi\left(\frac{A}{n_n}\right) n_c^r + n_n} A. \tag{1.11}$$

### 1.3.2 Solving the model: equilibrium inflows of colonists

Next we characterize the outcome of the colonial process. First, we turn to the inflow of colonists – how many people will choose to leave their country of origin and settle elsewhere? Ignoring transaction costs, we postulate that these decisions are based on a comparison of income levels at home and abroad. Assume potential colonists can earn a reservation wage $R$ in their country of origin (or earn $R$ engaging in peaceful trade e.g. with colonies). If potential colonists only migrate to start a new life elsewhere when the expected returns to such a move are at least $R$, then one out of four alternative types of equilibria will emerge. (1) $R = y_c r^* = w^*$, or an interior solution with some colonizers engaging in conflict and others in production; (2) $R = y_c r^* > w^*$, or a corner solution with some colonists engaged in conflict, but where it is not in the interest of settlers to become workers; (3) $R = w^* > g y_c^*$, or a corner solution where some colonists become workers, but where colonists will not engage in violent conflict; and finally (4) $R > w^*$ and $R > y_c r^*$, or a corner outcome where colonizers leave the new land undisturbed as they are better off at home.

To analyze the model in more detail, we first consider interior equilibrium (1). If such an interior solution exists, colonists must be indifferent between fighting and working:

$$y_c r^* = w^*(= R) \tag{1.12}$$

The number of colonist workers in equilibrium is uniquely defined, and may be obtained by equating the wage to the reservation wage:

$$(1-\alpha)s_c \left(\frac{\beta A}{n_n \Psi + \beta L}\right)^{\alpha} = R \tag{1.13}$$

It follows immediately that the number of colonist workers is given by:

$$n_c^p = \frac{A}{\left(\frac{R}{(1-\alpha)s_c}\right)^{\frac{1}{\alpha}}} - n_n \left(1 + \frac{\Psi}{\beta}\right), \tag{1.14}$$

so that

$$\frac{\partial n_c^p}{\partial n_n} = -\left(1 + \frac{\Psi}{\beta}\right) < 0 \tag{1.15}$$

Hence, perhaps not surprisingly, we find that for an interior solution there is a negative relationship between the number of natives and colonist workers. The reason is simply that increasing the number of natives depresses the wage rate, so that restoring equilibrium (where $w^* = R$ ) requires that some colonists leave the colony.

Next, consider the number of colonial settlers who choose to engage in conflict and contest the land base. Again, in equilibrium colonists must be indifferent between fighting and earning the reservation wage at home:

$$\alpha s_c \left(\frac{n_n \Psi + \beta L}{\beta A}\right)^{1-\alpha} \frac{\phi\left(\frac{A}{n_n}\right) n_c^r}{\phi\left(\frac{A}{n_n}\right) n_c^r + n_n} A = R. \tag{1.16}$$

In the case in which the $\phi$ function is constant, equation 1.16 describes a linear relationship between the number of colonists and the number of natives. However, it is likely that population densities matter in conflict, and one simple specification that captures this element is as follows (see Baker, 2003):

$$\phi\left(\frac{A}{n_n}\right) = \phi_0 \left(\frac{A}{n_n}\right). \tag{1.17}$$

Solving for the number of contesting colonists, we arrive at a quadratic relationship between the number of violent colonists and native population density:

$$n_c^r = \left(\frac{n_n\Psi + \beta(n_c^p + n_n)}{\beta A}\right)^{1-\alpha} \frac{A\alpha s_c}{R} - \frac{1}{\phi_0 A} n_n^2. \tag{1.18}$$

Hence, unlike the monotonous relation between colonist workers and native population density, we now find that the number of colonists pursuing the strategy of fighting to control land (and live off the rents) is a quadratic function of native population density.[16] The intuition is as follows. At low native population densities land is "cheap" (i.e rental payments for land are low) and wages are high. Colonists do better producing then, and conflict over land hardly occurs. In contrast, when the native population density is high, contesting land is expensive, as the physical return per unit of conflict effort is small – for any reasonable specification of conflict the returns to fighting go down as the opposite force gains strength (and this of course also applies to our contest function in equations 1.9 and 1.10). Since wages are also low then, the returns to working and contesting are both low, and only few potential colonists actually migrate to the colony (with the majority staying at home and earning $R$). At intermediate population densities, however, contesting land is feasible in the sense that per unit of conflict effort an intermediately-sized stretch of land can be controlled. Moreover, the value of land is rather high, as this production factor can now be combined with sufficient amounts of work labor. Under these conditions, a maximum number of colonists engages in conflict.

Note that the settlement of "aggressive" colonists peaks at an intermediate native population density $n_n^*$ (which is readily found by setting the first

[16] We also find a quadratic relation between the number of colonists engaged in conflict and natives when we take the number of colonists as fixed (so that in equilibrium we only require that $w^* = y_c r^*$ and not that the return to these activities equals $R$). Details are available from the authors on request.

derivative of equation 1.18 with respect to $n_n$ equal to zero). It is immediately apparent that the top of the parabola is a function of the conflict efficiency parameter $\phi_0$, and more specifically that $\partial n_n^*/\partial \phi_0 > 0$. That is, as colonial military technology improves, colonists are better able to take on formidable opposition, and the "turning point" shifts to reflect that. For sufficiently efficient military technologies, equation 1.18 becomes a monotonously upward-sloping curve, reflecting both that land becomes more valuable as native population densities go up, and also that grabbing and controlling land is still relatively easy for colonists, in spite of the numerous native opposition (that is: as long as the technological advance persists and is not eroded by copying, exchange, etc.).

In light of these results, it is relatively straightforward to interpret the corner solutions. There is a critical population density above which wages are so low that returns for (colonist) workers fall below $R$. Denote this threshold population density as $\bar{n}_n^p$. For $n_n > \bar{n}_n^p$, colonists prefer to not settle as workers. Similarly, there are critical lower and upper bounds on native population density below and above which colonists prefer not to enter and engage in conflict. Denote these thresholds by $\hat{n}_{n1}^r$ and $\hat{n}_{n2}^r$, respectively. For $n_n < \hat{n}_{n1}^r$, conflicts over land do not materialize because land is too cheap to warrant the effort. In contrast, for $n_n > \hat{n}_{n2}^r$ opposition is too fierce (so that physical returns to conflict effort are too low).

### 1.3.3 Linking conflict to inequality

The final challenge from a modeling perspective is to analyze how the inflow of colonists and the allocation of their labor is related to the distribution of income in colonial times. For this purpose, we consider the equilibrium allocation of colonists and their effort over a wide range of native population densities. Depending on the density, relative to the various threshold densities defined above, "colonies" can end up in an interior solution with colonists as both workers and landowners, or in a corner where one of these activities does not occur for lack of profitability. Depending on parameters, one of the following three cases describes the series of equilibrium outcomes as native density is increased from zero to $n_{max}$ (where it is assumed that $n_{max} > \hat{n}^r_{n2}$). Of course it is also possible that some of the threshold values "disappear" for certain combinations of parameters.[17]

Consider case A, depicted in Figure 1.2. It describes four qualitatively different equilibrium outcomes along a range of native population densities: (i) for sufficiently low population densities, an equilibrium emerges with colonist workers entering, but where there is no violent conflict over land as it is plentiful and inexpensive; (ii) for somewhat higher densities the returns to (colonist) labor fall below $R$, and colonist workers prefer to exit (since there is still no conflict this implies an outcome where the "colony" is left to its own devices); (iii) for intermediate population densities we have an outcome where colonists enter to grab the land and live off the rents; and finally (iv) for high population densities neither workers nor fighters will settle, as the return to both activities is smaller than $R$ (although of course trade might still occur).

The one thing to note is that for intermediate population densities, there are equilibrium outcomes where colonists are richer than natives. Colonists earn $R$ in equilibrium, living off the rents of the land they conquered, but competition on the labor market implies wages are lower than that (so that colonists would not deign to work themselves at those rates). In Figure 1.2, the case is highlighted with a "thick" arrow. Hence, even if we stack the deck against inequality by assuming equal productivity of colonist and native

[17] To be more precise, this happens when (i) $\bar{n}^p_n < 0$ so that colonists never choose to work as producers, since production technologies are so bad that even for the lowest native population densities, the return to labor falls short of R; (ii) $\hat{n}^r_{n1} < 0$, so that land is sufficiently valuable for colonists to trigger contests even in the absence of natives; or finally (iii) whenever $\hat{n}^r_{n2} < 0$, so that land is of so little value that it is never contested by any colonist. For cases (i) and (ii) we may find that, in equilibrium, natives and colonists do not earn the same income. This occurs whenever $n_n > \bar{n}^p_n$ and $\hat{n}^r_{n1} < n_n < \hat{n}^r_{n2}$, as discussed in more detail in the main text below.

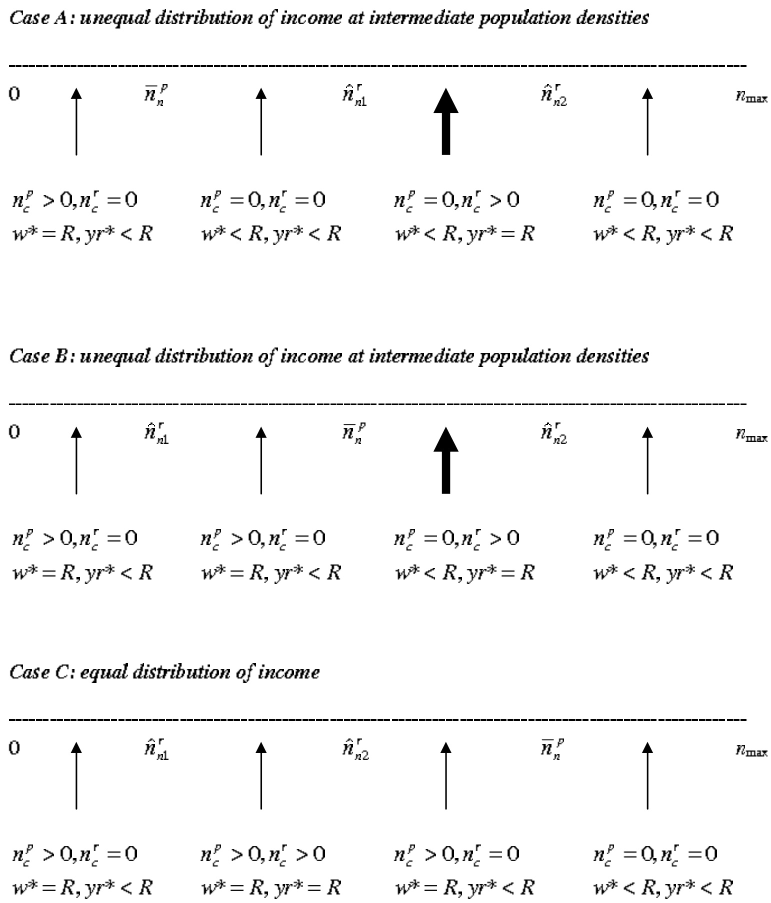


Figure 1.2: Equilibrium allocation of colonists and their effort for a range of native population densities

workers as wage laborers, and assuming free entry by colonists that drives down colonial income rents, we may still find that income inequality is an equilibrium outcome. This occurs whenever $n_n > \bar{n}_n^p$ and $\hat{n}_{n1}^r < n_n < \hat{n}_{n2}^r$. The same outcome appears in case B (and also in the degenerate cases where some of the threshold densities disappear). However, Figure 1.2 also indicates that inequality is not inevitable. For some parameter combinations, the sequence of threshold values is such that the conditions $n_n > \bar{n}_n^p$ and $\hat{n}_{n1}^r < n_n < \hat{n}_{n2}^r$ cannot be satisfied simultaneously. Then, every individual in the colony earns the same income. However, this case requires that colonists be unable to grab land by force (as the opposition is too intense), but that simultaneously it is feasible to enter as a migrant worker and earn a sufficiently high income. History does not provide many examples of such conditions.

The simple model therefore generates a number of testable implications. Our results with respect to colonial conflict intensity (section 1.3.3) as well as income patterns (section 1.3.2) both suggest a curvilinear relationship when regressing *historical* inequality measures on *historical* population density. Historical inequality should "top" at intermediate densities. Moreover, the relationship will also be influenced by the interaction with the colonists' level of offensive technology, with higher technology levels implying the ability to subdue more densely populated areas. Unfortunately, historical inequality data are not available to directly evaluate this proposition. Instead, we follow the social conflict view of institutional development, which predicts that equilibrium outcomes where a privileged class of landowners is better off than workers provides strong incentives for the élite to defend its position (through a range of political and economic mechanisms). If so, the relation between historical population density and inequality should carry over until today, linking *modern* income distributions to historical population densities in a non-linear fashion. This will be tested in the next section.

## 1.4 Empirical analysis

### 1.4.1 Data and descriptive statistics

Our main data requirements regard the measure of inequality – our dependent variable – and historical native population density in former colonies, our main explanatory variable. A frequent point of debate involving past studies on inequality has been the poor quality of the data. Deininger and Squire (1996, 1998) attempted to address these quality issues and proposed a new dataset, which was updated in 1997. Following Atkinson and Brandolini's (2001) criticism (based on observations for OECD countries from an alternative income survey) of the heterogeneous methodologies used to gather the

Table 1.1: Descriptive statistics of main variables

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Gini index | 83 | 47.421 | 9.168 | 28.3 | 64.9 |
| Top quintile income share | 69 | 52.074 | 7.966 | 32.8 | 68.1 |
| Average population density per square km around 1500 | 83 | 5.275 | 12.276 | 0 | 100.46 |
| Wheat-sugar ratio (in logs) | 70 | −0.011 | 0.143 | −0.393 | 0.578 |
| Latitude | 83 | 0.178 | 0.12 | 0.011 | 9.667 |
| Percent of land area in tropics | 76 | 0.777 | 0.378 | 0 | 1 |
| Distance from nearest coastline or navigable river in km | 76 | 344.125 | 358.182 | 7.952 | 1466.67 |

data presented by Deininger and Squire, the UN's World Institute for Development Economics Research (WIDER) produced a new inequality database, drawing on data from both these previous datasets. The recently updated version (UNU/WIDER, 2007) offers some further improvements regarding cross-country comparability and country coverage, including exclusive recent updates to the Deininger and Squire dataset, and more extended information on the survey methodologies and quality and reliability of the data. We use two measures of income inequality from this WIDER database, namely the Gini index (as calculated by WIDER according to a new and more accurate method) and the top quintile income share (in percent).

For each country, the earliest possible observation – to avoid capturing more recent economic trends (e.g., related to globalization) – of the highest possible quality was chosen that reflected the following fundamental criteria: (i) the income survey covered the entire population; (ii) the basic statistical unit was the household; and (iii) the survey was based on (disposable) income. As our sample of former colonies consists mostly of developing countries, some exceptions had to be made to avoid drastically reducing the number of observations: in one case, the income survey was based on family instead of household units; and for eight countries, the basic statistical unit was listed as uncertain (although the surveys were not generally of bad quality otherwise). Furthermore, for 18 countries there was only consumption or expenditure-based inequality data available.

The reliability of the observations is a further important point. WIDER distinguishes four quality categories according to whether the concepts underlying the survey are known and accepted, and according to the overall quality of the survey. Observations where both quality and concepts are unproblematic receive a rating of "1"; these include entries for virtually all high-income countries, and some more recent survey data for other countries. At the other extreme, observations to be treated as mere "memorandum" entries are classified as quality "4". We were generally able to avoid using worst-quality data on the Gini index, favoring more recent entries for the sake of reliability. However, this was often not the case for observations on top quintile shares, as they are less readily available; these data should therefore be treated with care. The trade-off between data quality and earliest-possible observation for each country resulted in 30% of the entries stemming from income surveys made after 1990, while the rest come mainly from the 1960s and 1970s, with some countries offering reliable inequality data for as early as the 1950s.[18] Descriptive statistics for the two inequality measures are presented in rows 1-2 of Table 1.1. Both show a wide gap between the least and most unequal country, New Zealand having the lowest inequality according to both measures, and the Central African Republic (CAR) and Colombia the highest according to the Gini index and the top quintile income share, respectively. As a comparison, the world mean Gini index and top quintile share are slightly lower than the ones for the colonies sample, at 42.647 and 48.926, respectively. However, the most unequal countries remain the CAR and Colombia in the global sample.

Our data on early population densities is taken from McEvedy and Jones (1978) and compiled according to the procedure in Acemoglu et al. (2002). We divide the estimated total population in 1500 by the country's total land

[18] All estimations were also perfomed with the Deininger and Squire (1996, 1998) dataset, as well as period average inequality data, with very similar results, confirming that the observed population density-inequality relationship is not due merely to the chosen dataset (results available upon request).

area in 1995 (in km$^2$, from WDI). In addition, we adjust the estimates for the percentage of *arable* land area where applicable (this becomes relevant for example in the desert countries of the Sahara), again using the information on the relative amount of arable land area contained in McEvedy and Jones (1978). For the most part, our data are analogous to those provided by Acemoglu et al. (2002), with some minor discrepancies due to approximation differences, as well as additional observations on non-colonies for our comparison estimations.[19] In both samples, the Seychelles were uninhabited before French colonization, while Egypt had by far the highest population density in 1500 of all former colonies, with over 100 inhabitants per square km on average (row 3 of Table 1.1).[20] Estimates on population numbers five hundred years ago are close approximations of the truth at best, which likely introduces a bias towards zero into our empirical results. In order at least to minimize the influence of outliers while at the same time preserving our full sample size, we perform all estimations below using log (*population density in 1500* +1).

We use four different variables to test the "competing" geography hypothesis of the origins of inequality proposed by ES and others, which holds that certain geophysical factors – e.g. a temperate climate, soils suitable to

[19] In a few cases, our data diverts from that of Acemoglu et al. (2002). Following the original information in McEvedy and Jones (1978), we assume that all Caribbean islands have the same population density of 1.33 (instead of 0.27 for Cuba and 1.46 for others as in Acemoglu et al. (2002)), with the exception of more populous Jamaica, which has a population density of 4.26 in both datasets. We also use the regional population estimates given by McEvedy and Jones (1978) for Malaysia and Singapore to calculate an average population density of 1.21, whereas Acemoglu et al. (2002) assume that Singapore had the same (very low) population density as the United States, namely 0.09. Similarly, our estimate of 9.16 for Hong Kong is based on the notes in McEvedy and Jones (1978), while Acemoglu et al. (2002) again assumed that Hong Kong had the same population density as the United States, even though mainland China in fact had a high average density of 10.72. Robustness tests show that our results are not influenced by the differences.

[20] Egypt was by no means the world's most populous country in 1500: Japan had nearly triple its population density, at an average 287.53 inhabitants per square km.

growing staples such as grains, and proximity to the coast – have favored the emergence of more prosperous, egalitarian societies. The first variable which captures one of these geographical aspects, *lwheatsugar*, leans directly on the hypothesis of ES: it measures the soil suitability for growing wheat versus sugarcane, expressed as the (log) ratio of the share of arable land suitable for growing wheat to the share suitable for sugarcane, from Easterly (2007). A lower ratio indicates a propensity to grow a high-yield, plantation-style crop, with the ensuing emergence of a more unequal society, and vice versa. Jamaica shows the greatest soil suitability for growing sugarcane, followed by Guatemala, the Philippines and the Dominican Republic. Next, *latitude* is defined as the absolute distance from the Equator and is taken from La Porta et al. (1999). A greater distance from the Equator is linked to more temperate climates, and to more highly developed countries with less unequal income distributions. A similar concept lies behind the variable *tropics*, which indicates a country's land area in the geographical tropics in percent, while *distcr* measures the mean distance to the nearest coastline or sea-navigable river in km, according to the reasoning that coastal countries tend to be more prosperous due to trade. Both of these last variables are from the Gallup, Mellinger and Sachs geography database (available via the *Center for International Development* website).

As data on early reserves or production of minerals for a large number of countries are virtually impossible to come by, we constructed a dummy variable (*precious*) to capture the possible influence of precious metals on inequality suggested by ES. Countries are assigned value "1" if there was a known presence of gold or silver (or both) in the 16th century, and zero otherwise. Several historical studies served as the basis for this classification, including Del Mar (1902) and the contributions edited by Kellenbenz (1981). 29 former colonies from all three regions – the Americas, Africa, and Asia – are reported to have had substantial precious metal deposits at the time.

Finally, we took into account the colonizers' level of (military) technology by constructing a dummy variable for a country colonized with "early" military technology, based on information on the year of colonization from the CIA World Factbook and the U.S. Department of State. We chose a generous cut-off date of 1700 in order to avoid biasing the empirical results in our favor; as described in Section 2, historians in fact most commonly date the period of the military revolution between 1560-1660. The 29 countries colonized before the turn of the 18th century are listed as "1", including all of the New World colonies and the Philippines.[21]

### 1.4.2 Empirical results using the Gini index

Table 1.2: Gini index and population density circa 1500

| sample | world | colonies | colonies early tech | colonies new tech | colonies |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| lpopdens | −5.307*** | −3.212*** | 9.872*** | −3.672*** | −3.672*** |
| | (0.79) | (0.92) | (3.70) | (1.03) | (1.03) |
| earlytech*lpopdens | | | | | 13.544*** |
| | | | | | (3.84) |
| earlytech | | | | | −7.369* |
| | | | | | (4.17) |
| Obs | 130 | 83 | 29 | 54 | 83 |
| $R^2$ | 0.29 | 0.11 | 0.25 | 0.16 | 0.25 |
| F-stat | 44.42*** | 11.77*** | 6.64** | 12.17*** | 17.85*** |

*Notes*: All regressions are OLS. Dependent variable is inequality, measured by Gini index. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

In Table 1.2, we show some comparison estimations using population density in 1500 to explain modern-day inequality, as measured by the Gini index. For both the entire world and the former colonies sample (columns (1)-(2)), early population density has a strong negative influence on inequality, i.e. a higher population density in 1500 is linked to lower inequality today. This

[21] As mentioned above, several European countries maintained coastal enclaves in Africa and Asia during the 16th-17th centuries. However, these are not considered as "full" colonies, because the majority of the present-day national land area remained under native control until well into the 18th or even 19th century.

finding is already in marked contrast to the reasoning of ES. However, this simple approach does not adequately capture the whole breadth of the population density-inequality relationship. As discussed above, there was a change in the colonization pattern, where population densities are linked to the highest observed inequality rates, around the turn of the 18th century. This change roughly coincides with the end of the military revolution, which – as we have shown – enabled Europeans to invade the more populous areas which had before defied conquest on the one hand, but at the same time could not avoid the inevitable decline in the territory size which could be put under tight colonial control of a narrow white élite.

The change in colonization patterns becomes obvious once we separate the colony sample into two subsamples according to the year of colonization. In column (3), we see that the countries colonized with the "early" technology show a strong positive relationship between population density and inequality. This pattern is in accordance with the hypothesis of ES that more populous colonies tended to give rise to extractive-type economic systems with highly unequal societies. This pattern is confirmed empirically for the Americas and the Philippines, and is carried through to some further colonies in the mid-range of population density as the new technology becomes available. However, the relationship is reversed as more and more populous colonies are added, leading to the strong negative relationship with inequality for the "new technology" colonies subsample in column (4).

The opposite signs and highly significant coefficients in the two subsamples contradict the common wisdom of a linear relationship, instead confirming our own theory of an inverse-U shaped relationship.[22] Up to a certain point, higher native population densities favor forceful control by colonists and the emergence of unequal, extractive social and economic structures. But very populous countries will enable less and less aggressive colonial policies, re-

[22] The existence of two different subsamples with opposite slopes is confirmed by tests using the clusters approach (in GAUSS) following Hansen (2000), which moreover does not reject our cut-off date of 1700, albeit preferring the post-industrial 1840 as the cut-off.

sulting in a tendency towards maintaining pre-colonial social structures and not creating highly unequal societies with a strong colonist élite.

We would like to keep the entire sample of former colonies together both because of the relatively small sample size, and in order to test our hypothesis against other common explanations of the colonial origins of inequality, including geography and precious metals, which are not assumed to have differing (i.e. non-linear) effects for the two subsamples. We can achieve this by adding an interaction term *earlytech*lpopdens* between the technology dummy and early population density, which will assume value 0 for all observations after the military revolution. Our basic regression equation therefore becomes:[23]

$$Inequality = \alpha_0 + \alpha_1 lpopdens + \alpha_2 earlytech^* lpopdens + \alpha_3 earlytech + \varepsilon. \tag{1.19}$$

The coefficient $\alpha_2$ for *earlytech*lpopdens*, shown in column (5), gives the slope for the countries colonized before the military revolution: one can easily see that it is identical to the coefficient in column (3) by subtracting the coefficient $\alpha_1$ for the later-colonized countries, $13.544 - 3.672 = 9.872$.

Together, our variables can account for one fourth of the variation in inequality in former colonies, which we believe is quite substantial considering the complexity of the issue. The results also suggest that up to the turning point, increasing (log) population density by one standard deviation (0.93) produces a corresponding one-standard-deviation increase in inequality ($0.93^*9.872/9.168$). After the "cusp" however, the same change in (log) population density decreases inequality by well over one-third of a standard deviation ($0.93^*(-3.672)/9.168 = 0.37$).

Using this strategy, we will now proceed to test our hypothesis against

[23] This simple technique for taking into account differing slope coefficients in subsamples by adding an interaction with a dummy variable – sometimes termed a "structural break" model – was first formally described in Suits (1957). See e.g. Kennedy (2003: Ch. 14) for further details.

Table 1.3: "Horse race" of colonial determinants of inequality (measured by Gini index)

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| lpopdens1500 | −4.061*** | −3.593*** | −3.966*** | −4.108*** | −4.155*** | −5.090*** |
| | (1.11) | (1.06) | (1.21) | (1.16) | (1.06) | (1.19) |
| earlytech*lpopdens | 12.11** | 11.10*** | 12.63*** | 14.07*** | 14.29*** | 13.82*** |
| | (5.65) | (3.83) | (4.45) | (3.89) | (3.44) | (5.22) |
| earlytech | −6.121 | −5.042 | −6.983 | −8.282* | −9.696** | −7.982 |
| | (5.22) | (4.35) | (4.81) | (4.36) | (4.11) | (5.23) |
| lwheatsugar | −9.690 | | | | | −5.121 |
| | (8.04) | | | | | (10.1) |
| latitude | | −18.31** | | | | −43.84*** |
| | | (8.79) | | | | (15.0) |
| tropics | | | 3.272 | | | −9.697* |
| | | | (3.21) | | | (5.64) |
| distcr | | | | −0.001 | | 0.001 |
| | | | | (0.004) | | (0.003) |
| precious | | | | | 3.882** | 3.119 |
| | | | | | (1.95) | (2.15) |
| Obs | 70 | 83 | 76 | 76 | 83 | 69 |
| $R^2$ | 0.31 | 0.30 | 0.28 | 0.27 | 0.28 | 0.42 |
| F-stat | 15.46*** | 18.14*** | 15.26*** | 13.96*** | 18.27*** | 24.27*** |

*Notes*: All regressions are OLS for ex-colonies sample. Dependent variable is inequality, measured by Gini index. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

other variables. In Table 1.3, we one-by-one add variables corresponding to the other two explanations for inequality proposed by ES, namely geography and the exploitation of precious metals. The "horse race" of the explanations on the colonial origins of inequality clearly shows that our hypothesis holds up very well to the test. The early population density coefficients remain consistently highly significant and with opposite signs, with little variation in the magnitude of the impact on inequality, even when we add all other variables together in column (6). We do note however that the "early technology" dummy is not always significant.

As far as the other variables are concerned, the wheat-sugar ratio and distance to the sea or a navigable river are not good predictors of inequality in former colonies, although they each enter with the expected sign. Tropical location is weakly negatively significant only when we simultaneously control for all other effects. The only geographic measure which holds its own against the early population density variables is latitude, suggesting that greater proximity to the Equator does have an independent negative impact on egalitarian income distribution in former colonies. Interestingly, the early presence of precious metals has a relatively strong effect on inequality, apparently confirming the hypothesis of ES that mineral exploitation tended to produce more unequal societies. However, this effect is not robust to controlling for geographical factors. In separate estimations (available upon request), we also controlled for further effects, including regions, colonial and legal origin, and ethnic fractionalization, none of which influenced our results.

It is possible that our results are being influenced by the presence of outliers. The most commonly cited outliers in the literature on colonial roots of economic development are the so-called "neo-Europes" – Canada, the U.S., Australia, and New Zealand. In our case, one could well imagine that their inclusion would bias the results in our favor, as they were all relatively sparsely populated around 1500 and demonstrate low modern inequality levels. Tests confirm this possibility; New Zealand, Canada and Australia in particular often appear as outliers.[24] In Table 1.4, we therefore repeat our main estimations without these four countries. All of our previous findings regarding the inverse-U shaped relationship between early population density and inequality are confirmed, while the influence of the geographic variables and the precious metals dummy is further weakened. Moreover, the regression fit improves to 0.32 in our basic estimation (column (1)).

The empirical results so far have very much favored our hypothesis that there was a trade-off between higher native population, with its opportunity for cheap labor, against the costs of conquering and controlling ever more densely populated countries. This view has also performed well when con-

[24] Further outliers indicated by the tests (using studentized residuals and overall measures of influence) include Laos, Jamaica, Brazil, and Suriname. All of our results are reinforced when dropping these countries one at a time, as well as collectively.

Table 1.4: Inequality (measured by Gini index) in ex-colonies, excluding neo-Europes

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| lpopdens | $-4.775^{***}$ | $-5.379^{***}$ | $-4.713^{***}$ | $-5.554^{***}$ | $-5.462^{***}$ | $-5.138^{***}$ | $-6.386^{***}$ |
| | (0.81) | (0.86) | (0.86) | (0.82) | (0.81) | (0.85) | (0.80) |
| earlytech*lpopdens | $11.50^{***}$ | $12.29^{**}$ | $11.30^{***}$ | $13.07^{***}$ | $12.47^{***}$ | $12.72^{***}$ | $15.45^{***}$ |
| | (3.97) | (5.36) | (4.05) | (4.30) | (4.05) | (3.90) | (5.42) |
| earlytech | $-6.853$ | $-7.116$ | $-6.610$ | $-8.705^{*}$ | $-8.390^{**}$ | $-9.262^{**}$ | $-11.54^{**}$ |
| | (4.20) | (4.94) | (4.35) | (4.46) | (4.24) | (4.50) | (5.14) |
| lwheatsugar | | $-2.797$ | | | | | $-5.858$ |
| | | (7.76) | | | | | (9.72) |
| latitude | | | $-3.878$ | | | | $-34.70^{**}$ |
| | | | (8.25) | | | | (16.2) |
| tropics | | | | $-1.363$ | | | $-10.77^{**}$ |
| | | | | (2.22) | | | (4.99) |
| distcr | | | | | $-0.0005$ | | 0.0002 |
| | | | | | (0.004) | | (0.003) |
| precious | | | | | | 2.986 | 3.203 |
| | | | | | | (1.97) | (2.15) |
| Obs | 79 | 66 | 79 | 72 | 72 | 79 | 65 |
| $R^2$ | 0.32 | 0.39 | 0.32 | 0.36 | 0.36 | 0.34 | 0.45 |
| F-stat | $24.96^{***}$ | $22.32^{***}$ | $18.20^{***}$ | $21.66^{***}$ | $21.38^{***}$ | $22.45^{***}$ | $18.87^{***}$ |

*Notes*: All regressions are OLS for ex-colonies sample without neo-Europes (Australia, Canada, NZ and USA). Dependent variable is inequality, measured by Gini index. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 1.5: Top quintile income share and population density circa 1500

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | | | colonies | colonies | |
| sample | world | colonies | early tech | new tech | colonies |
| lpopdens | −2.868*** | −1.255 | 8.701*** | −1.875 | −1.875 |
| | (0.70) | (0.96) | (2.86) | (1.16) | (1.16) |
| earlytech*lpopdens | | | | | 10.58*** |
| | | | | | (3.09) |
| earlytech | | | | | −7.175* |
| | | | | | (3.71) |
| Obs | 103 | 69 | 27 | 42 | 69 |
| $R^2$ | 0.14 | 0.02 | 0.23 | 0.06 | 0.13 |
| F-stat | 16.33*** | 1.65 | 8.55*** | 2.48 | 5.36*** |

*Notes*: All regressions are OLS. Dependent variable is inequality, measured by income share of top quintile. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

fronted with alternative explanations of the historical causes of income distributions. In the next subsection, we will use a different measure of inequality to further test our hypothesis.

### 1.4.3 Results using the top quintile income share

The income share of the richest part of the population offers a different way of measuring inequality: the higher the wealth concentration in the upper quintile, the more unequal the distribution of monetary wealth in the society as a whole. Unfortunately – as we mentioned above – data on quintile income shares is both scarcer and of worse quality than that on Gini coefficients. Therefore, the following results should be interpreted with some care.

Tables 1.5-1.7 present the same estimations shown above with the top quintile income share as the dependent variable. Results are similar, although in Tables 1.5-1.6 we see that population density for “later” colonies sometimes narrowly misses conventional significance levels. Also, the statistical properties of the specifications using the top quintile income share are less satisfying than those for the Gini index, evident from the low values for the F-statistics and R-squareds. From Table 1.5, it follows that for the

Table 1.6: "Horse race" of colonial determinants of inequality (measured by top quintile income share)

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| lpopdens | −2.105* | −1.806* | −1.935 | −2.214* | −2.497** | −2.743** |
| | (1.19) | (1.00) | (1.20) | (1.26) | (1.24) | (1.24) |
| earlytech*lpopdens | 8.383* | 8.027** | 8.588** | 10.31*** | 12.03*** | 9.595* |
| | (4.66) | (3.34) | (3.71) | (3.11) | (2.97) | (5.41) |
| earlytech | −6.591 | −4.886 | −6.226 | −7.811** | −10.37*** | −7.809 |
| | (4.41) | (3.80) | (4.19) | (3.76) | (3.81) | (4.86) |
| lwheatsugar | −12.44 | | | | | −3.403 |
| | (8.48) | | | | | (11.5) |
| latitude | | −21.69*** | | | | −30.75* |
| | | (7.58) | | | | (16.3) |
| tropics | | | 5.499* | | | −4.451 |
| | | | (3.13) | | | (6.25) |
| distcr | | | | −0.002 | | −0.0004 |
| | | | | (0.003) | | (0.003) |
| precious | | | | | 4.097** | 2.110 |
| | | | | | (1.86) | (2.00) |
| Obs | 60 | 69 | 64 | 64 | 69 | 59 |
| $R^2$ | 0.18 | 0.23 | 0.21 | 0.16 | 0.18 | 0.29 |
| F-stat | 7.22*** | 7.9*** | 7.80*** | 4.39*** | 4.82*** | 6.15*** |

*Notes*: All regressions are OLS for ex-colonies sample. Dependent variable is inequality, measured by income share of top quintile. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

upward-sloping curve, an increase of one standard deviation in (log) population density in 1500 would have caused the top quintile's income share to increase by just over one standard deviation ($0.93 * 8.701/7.966$), all other things equal. On the downward-sloping side, the same change in population density would lead to an average decrease in inequality by one-fifth of a standard deviation ($0.93 * (-1.875)/9.168$). In Table 1.6, we see that results are not influenced greatly by the addition of the geographical variables and the precious metals dummy. As before, latitude and the presence of precious metals prove the most significant additional factors, with tropical location significant at the 10%-level when added on its own (column (3)).

Estimations using the top quintile income share are particularly prone to outlier bias. This is evident from the results shown in Table 1.7, where

Table 1.7: Inequality (measured by top quintile income share) in ex-colonies, excluding neo-Europes

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| lpopdens | −3.184*** | −3.677*** | −3.029*** | −3.709*** | −3.773*** | −3.681*** | −4.399*** |
| | (0.81) | (0.77) | (0.83) | (0.79) | (0.77) | (0.96) | (0.87) |
| earlytech*lpopdens | 8.942*** | 9.757** | 8.875*** | 9.584*** | 9.351*** | 11.23*** | 12.60** |
| | (3.05) | (4.07) | (3.29) | (3.20) | (3.16) | (3.65) | (5.85) |
| earlytech | −7.402** | −8.501** | −7.233** | −8.644** | −9.093*** | −11.05** | −13.10*** |
| | (3.37) | (3.63) | (3.55) | (3.45) | (3.34) | (4.37) | (4.90) |
| lwheatsugar | | −0.822 | | | | | −1.854 |
| | | (6.96) | | | | | (11.2) |
| latitude | | | −8.863 | | | | −25.27 |
| | | | (7.70) | | | | (20.6) |
| tropics | | | | 0.327 | | | −6.672 |
| | | | | (1.84) | | | (5.24) |
| distcr | | | | | −0.002 | | −0.002 |
| | | | | | (0.003) | | (0.003) |
| precious | | | | | | 3.307 | 2.592 |
| | | | | | | (2.10) | (2.23) |
| Obs | 65 | 56 | 65 | 60 | 60 | 65 | 55 |
| $R^2$ | 0.18 | 0.24 | 0.19 | 0.23 | 0.24 | 0.22 | 0.30 |
| F-stat | 8.85*** | 9.44*** | 7.47*** | 8.91*** | 9.05*** | 5.87*** | 4.86*** |

*Notes*: All regressions are OLS for ex-colonies sample without neo-Europes (Australia, Canada, NZ and USA). Dependent variable is inequality, measured by top quintile income share. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 1.8: Population density, inequality and income levels and growth

| | (1) | (2) |
|---|---|---|
| Dependent variable | Instruments lpopdens & interaction | Instrument lpopdens |
| **growth 1970-2000** (N=77) | **-0.029** | **-0.01** |
| r.s.e. | 0.036 | 0.07 |
| 1st stage F-stat | 14.72 | 7.98 |
| Shea $R^2$ | 0.3 | 0.12 |
| Anderson IV relevance test $p$-value | 0.000 | 0.002 |
| **income 2000** (N=82) | **0.071**$^{***}$ | **0.142**$^{**}$ |
| r.s.e. | 0.025 | 0.068 |
| 1st stage F-stat | 17.12 | 10.92 |
| Shea $R^2$ | 0.24 | 0.10 |
| Anderson IV relevance test $p$-value | 0.000 | 0.003 |

*Notes*: All regressions are 2SLS, with inequality measured by the Gini index. The growth regressions include the (log of) initial income as a basic control variable in the second stage.

we omit the neo-Europes.[25] Not only do we get a consistent, highly significant inverted-U shaped relationship between early population density and inequality; the regression fits and F-statistics are also considerably improved. Interestingly, none of the additional variables prove significant when we drop the neo-European former colonies, suggesting that the influence of population density dominates that of geography and precious metals in former colonies.

### 1.4.4 Linking inequality to growth and income levels

Finally, we test the usefulness of the analysis by revisiting the contested relationship between inequality on the one hand, and growth and development on the other. As argued above, the theoretical and empirical literature on the nature of this relation is divided. Our analysis suggests we could use historical population density, combined with the interaction term, in a first stage regression as instruments to predict inequality in the former colonies.

[25] Again, Canada, New Zealand and Australia were indicated as outliers by several tests, along with Brazil and Egypt. Dropping all outliers reinforces the non-linear relationship between population density and inequality and pushes up the F-statistics and R-squareds (detailed results available upon request).

In a second stage, then, we can examine the causal relationship running from inequality to growth and income levels. To illustrate the importance of careful instrument selection, we also demonstrate similar results for a naïve model based on a simple linear relation between historic population density and inequality. Representative results for the second-stage coefficients for inequality measured by the Gini index are reported in Table 1.8.

Two results stand out. First, when using our preferred set of instruments, there does not appear to be a causal link from inequality to growth in the former colonies, although inequality does appear to have a negative growth impact (column (1)). There is a significant positive link between inequality and current income levels, but this becomes insignificant (p=0.161) once we control for regional effects. Perhaps the various positive and negative effects tend to offset and neutralize each other, the implication being that any correlation between inequality and growth (or income levels) is driven by either reverse causality or omitted variables.

Second, the choice of instruments matters for the results of the second stage. The naïve model, based on a linear relation between historical population density and modern inequality in the first stage, performs worse than our preferred model. Although the signs are the same, the first-stage test statistics are weaker and show that the explanatory power of the more complex model with the interaction term is superior.

## 1.5 Conclusions

The distribution of income is a key topic in economic research, as well as an important issue for policymakers. It is of interest in and of itself, but it is also relevant because inequality has been linked to enhanced or depressed economic growth rates. This paper examines the historical origins of modern income distribution. Our story is related to that of economic historians Engerman and Sokoloff (1997, 2000, 2002), who focused on the importance of colonial-era factor endowments for development paths in the Americas. They argued that a climate and soil conducive to growing high-value crops such as sugarcane; the existence of gold and silver mines; and - most importantly - a large native population providing cheap labor tended to bring forth social and political structures which favored the colonial élites. The institutional set-ups created to guarantee the status of the privileged classes influenced economic development and led to the persistence of these early forms of inequality well into the modern period.

However, we argue that the crucial influence of native population density on European colonization and the subsequent distribution of wealth was not uniform across all colonies. Instead, it was determined by the ratio of land to native inhabitants which the early colonizers were confronted with, and by the (military) technology of which they disposed: essentially, the colonizers traded off a higher native population, with its promise of cheap labor, against the cost of military conflict and control. This lead to an inverse-U shaped relationship between population density at the time of colonization and the income distribution in former colonies. Specifically, we hypothesize that (i) very low native population densities tended to lead to settler-type colonization, with more egalitarian social and political structures and hence more equal wealth distributions (as in previous literature); at the other end of the spectrum, (ii) very high native population densities tended to lead to the adaptation of existing social and institutional structures by the colonizers - as forced change would have been too costly - again resulting in more equal wealth distributions. In between lie those colonies where (iii) native population density was low enough to permit conquest and control by force, and yet high enough to make cheap native labor an attractive alternative to own work, creating unequal societies with a large income gap between the colonizing élite and the rest of the population.

We develop a model which reflects the defensive capabilities of a larger native population on the one hand, and the returns to peaceful settlement or aggressive conquest for the colonizers on the other. The relative technological level of the colonists plays an important role, as a better technology permits the forceful occupation and subjugation of the more densely populated areas, with the possibility of a larger pool of cheap labor force to work the conquered land. However, when the technological advantage of the colonizers wanes, conflict becomes too costly with respect to more peaceful forms of interaction. The result is that at intermediate levels of native population density, we can expect the highest degree of conflict and the largest proportion of native labor forced to work for cheap wage rates, and therefore the highest level of income inequality between colonizers and colonized.

The findings of the model are tested empirically for a broad sample of former colonies by regressing native population densities around 1500 on modern-day income distributions, measured by the Gini index and the income share of the top quintile. We also construct a dummy variable to reflect whether a country was colonized before or after the military revolution of the 17th century, which brought several fundamental advances in European military technology. The results confirm the inverse-U shaped link between early population density and inequality, as well as the role of the interaction between population density in the colonies and the technological level of the colonizers in determining subsequent development patterns. We further refine the understanding of the roots of economic development by showing that early native population density was more important in determining European colonization than geographical factors such as soil quality, climate or access to a navigable port, or even the presence of precious metals. We also use the results to motivate the choice of historical population density and an interaction terms as instruments for inequality in regressions explaining income growth or levels. Our 2SLS regressions imply that there is no strong causal relation running from inequality to growth or income levels in our sample of former colonies.

The results suggest that no one theory of the influence of colonial factor endowments on development patterns can fit all countries, but that there are some important non-linearities which must be considered when trying to understand the origins of economic development.

# Chapter 2

# Cursing the blessings? Natural resource abundance, institutions, and economic growth*

Since Sachs and Warner's (1995a) contribution, there has been a lively debate on the so-called natural resource curse. This paper re-examines the effects of natural resource abundance on economic growth using new measures of resource endowment and considering the role of institutional quality. We find a positive direct empirical relationship between natural resource abundance and economic growth. In both OLS and 2SLS regressions, the positive resource effects are particularly strong for subsoil wealth. Our results also show no evidence of negative indirect effects of natural resources through the institutional channel.

* This chapter has been published in *World Development*.

## 2.1 Introduction

Natural resources seem to have been more of a curse than a blessing for many countries. Numerous researchers have supported the view that resource-poor countries often outperform resource-rich countries in economic growth. Sachs and Warner (1995a) – hereafter referred to as SW – made a major contribution when they found a negative association between natural resource abundance and growth in a large cross-country study,[1] and a substantial number of papers has since considered the natural resource curse hypothesis from different points of view. For example, Auty (1997, 2001) tries to explain the curse historically; while Ross (1999, 2001), Jensen and Wantchekon (2004), Collier and Hoeffler (2005), and Hodler (2006) focus on the negative associations between resource abundance and the stability and quality of the political system.

The explicit consideration of various transmission channels of the effects of natural resource abundance on economic growth has lead to more differentiated – and ambiguous – results. For example, Gylfason (2001), Bravo-Ortega and De Gregorio (2005), and Stijns (2006) concentrate on different links with human capital. The first shows that the negative growth effects of natural resources stem from lower education spending and less schooling in resource-rich countries. The second find that the negative resource effects can in fact be *offset* by higher education levels, making natural resource abundance a boon for countries with high human capital levels. And the third concludes that per capita rents from natural resources are positively correlated with human capital accumulation. Baland and Francois (2000) and Torvik (2002) focus on the effects of natural resource abundance on rent-seeking behavior and income; while Manzano and Rigobon (2001) believe that the real problem for growth is the debt overhang in resource-rich countries. The Dutch disease hypothesis is examined by Stijns (2003), who confirms the typical sectoral change pattern but finds little evidence for overall negative resource

[1] The same authors contributed several more studies on the resource curse, see Sachs and Warner (1997, 1999, 2001), as well as Rodriguez and Sachs (1999).

effects on growth; and by Matsen and Torvik (2005), who propose that long-term growth can be positive provided the savings path is adjusted to take into account the relative importance of the traded and non-traded goods sectors. Hausmann and Rigobon (2002) consider the trade structure and show that (export) diversified economies are less likely to suffer negative effects of natural resource wealth.

In this paper, we re-examine two main aspects of the resource curse literature and find new cross-country evidence contradicting previous findings of detrimental growth effects of natural resource wealth. The first aspect regards the measurement of natural resource abundance. Most empirical studies confirming the resource curse published over the past decade have used the SW (or a similar) measure, which estimates resource abundance based on the share of primary exports in GDP at the beginning of the observation period. We evaluate the validity of this indicator and propose two alternative indicators – developed by the World Bank (1997, 2005) and measuring per capita mineral and total natural resource wealth, respectively – which in our view better capture a country's natural resource abundance. The second aspect concentrates on the importance of institutional quality in the economic growth and development process. Despite several recent studies showing that "institutions matter" for development (e.g., Knack and Keefer, 1995; La Porta et al., 1999; Acemoglu et al., 2001), the role of institutional quality has received limited attention in work on growth with resource abundance.[2] A review of the literature shows that institutions may however play a critical role in determining the economic performance of resource-rich economies, and should therefore be awarded a more prominent place in the analysis. The results of our cross-country estimations show no evidence of a negative growth effect of natural resource abundance. Using the new measures of natural resource wealth, we instead find a positive direct association with economic growth over the period 1970-2000, which is confirmed when we

[2] A notable recent contribution by Robinson et al. (2006) offers a rare theoretical explanation of the resource curse based on a country's political institutions.

consider the role of institutional quality. The findings are consistently highly significant when we concentrate on mineral resources, which runs contrary to most of the resource-and-growth literature. Also, our estimations do not confirm the negative effects of resource abundance through institutional quality found in several other studies. Interestingly, adding an interaction term suggests that the beneficial resource effects diminish as institutional quality increases, although the overall effects remain strongly positive. The positive results hold both in ordinary least squares (OLS) and two-stage least squares (2SLS) estimations which consider the endogeneity of institutions, and they are robust to the inclusion of a wide range of additional control variables from the growth literature.

It is not within the scope of this paper to offer policy recommendations to resource-rich countries, but the results do question development advice based on the idea that there is a general "natural resource curse". The findings strongly suggest that a more cautious approach is called for when evaluating the development effects of natural resource abundance: the "resource curse" should be re-assessed before incurring a policy error made trying to avoid it.

The next section takes a closer look at various measures of natural resource abundance used in the literature and proposes some alternatives, and then discusses the importance of considering institutional quality. Section 2.3 presents results of OLS and 2SLS regressions of the growth rates of GDP per capita on our measures of natural resource endowment and institutional quality, and section 2.4 concludes.

## 2.2 The natural resource curse hypothesis

### 2.2.1 Measuring natural resource abundance

Most resource-and-growth research has focused on the "curse" effect of absolute natural resource abundance *per se*, both empirically and theoretically (e.g., Leite and Weidmann, 2002; Torvik, 2002; Hodler, 2006). However, following Sachs and Warner (1995a, 1997), primary exports over GDP have constituted the preferred indicator of natural resource abundance in empirical analysis.[3] SW's measure of "resource intensity", *sxp*, is easily available and has been employed by numerous researchers who confirmed the negative growth effects of natural resource wealth. But if the aim is to quantify natural resource abundance, then primary exports seem an unsatisfactory measure for two main reasons.[4]

First, one should expect any conclusion on a "curse" of natural resource *wealth* or *abundance* to be based on the closest possible approximation of such wealth – in other words: some measure corresponding to the widely used indicator of economic wealth, income (GDP) per capita. Assuming a strong positive correlation between natural resource abundance and natural resource exports is by no means obvious given counter-examples of resource-rich countries with relatively low primary exports such as Australia and Germany. Moreover, we could also plausibly argue that a dominant share of primary resource exports in GDP is a strong indication for an overly specialized economy. Slow growth in countries with a large share of primary exports may therefore be due more to economic policy leading to a high economic dependence on the natural resource sector, rather than a direct natural resource "curse".[5] Second, it is worth noting that the resource export variable is quite volatile, suggesting that the period average would in any case be a better measure than the beginning-of-period value employed in the literature (Ledermann and Maloney, 2003).[6]

Empirically, variations in the setup of the resource exports variable have cast substantial doubt on the resource curse hypothesis. For example, Le-

[3] Although some studies, such as Mehlum et al. (2006), actually focus on the impact of resource rents when they speak of the "resource abundance curse", they use the SW measure for empirical estimations.

[4] Wright and Czelusta (2004) and Stijns (2005) offer earlier critiques of this indicator.

[5] See Brunnschweiler and Bulte (2007) for a closer look at this possibility and its implications for the resource curse.

[6] *sxp* is calculated for 1970, while the observation period in SW is 1970-1989.

dermann and Maloney (2003) find *positive* growth effects using the share of primary exports in total exports and primary exports over total labor force. Davis (1995) used the share of mineral exports in total merchandise exports as one of his natural resource proxies, showing a positive relationship with economic development. Leite and Weidmann (2002) and Sala-i-Martin and Subramanian (2003) find ambiguous growth effects when disaggregating resource exports into agricultural, and fuel and non-fuel mineral products. Neumayer (2004) introduces another variation on the resource curse theme: although still using SW's resource exports variable, he takes growth in *genuine* income, i.e. GDP minus depreciation of produced and natural capital, as the dependent variable to find a negative, albeit weakened, resource effect.

Other empirical research does not rely on export data at all, but has instead employed completely different measures of natural resource abundance. For example, Atkinson and Hamilton (2003) use the ratio of resource rents to GDP to show both positive and negative economic effects, and Stijns (2006) also argues in favor of using resource rent data, although he prefers per capita measures. In this group of empirical work as well, differentiating between various types of resources has delivered interesting results. When classified by indices, economies dependent on "point-source" resource extraction – i.e. minerals and plantation crops characterized by localized, intensive production – often show evidence of worse economic performance and institutions than economies dependent on more "diffuse" resources, i.e. characterized by more extensive production (Isham et al., 2005). Mineral production over GDP however delivers less clearcut results: using this measure, Davis (1995) finds a positive relationship with economic growth, while Papyrakis and Gerlagh (2004) find both positive and negative growth effects, with the negative ones prevailing. Fuel and non-fuel mineral reserve and production data, as well as land endowment – all measured per 1'000 inhabitants – again show ambiguous effects on economic growth (Stijns, 2005). Finally, Ding and Field (2005) use World Bank data on natural resource wealth to re-estimate SW's basic regression, as well as a three-equation model to consider the effects of

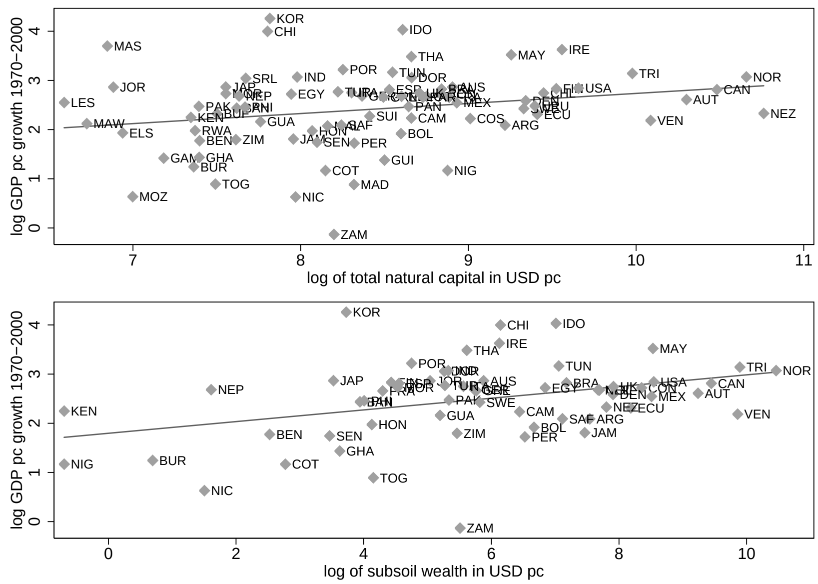


Figure 2.1: Natural resource wealth and growth

*Notes*: Regression fit using World Bank natural wealth data measured in USD per capita (pc). See Appendix for data and regression details.

resources on human capital. They find negative growth effects of natural resources as a share of total produced capital, and positive growth effects of natural resources per capita; but both indicators become insignificant in the three-equation model. However, their simple approach leaves many open questions on the robustness of the results.

Hence, as a first step in re-examining the hypothesis of a curse of natural resource *abundance* – as opposed to the curse of a *dependence* on natural resource *exports* actually found by much of the literature – we compare SW's primary exports indicator *sxp* with several alternative measures of natural resource endowment. We collected data on fuel and non-fuel mineral production in 1970 from the *World Mineral Statistics* (IGS, 1978) and British Petroleum (for natural gas), and used them both separately and as an aggregate, denoted by *fuelmin*, *nonfuelmin*, and *min*, respectively. Additionally, these indicators were calculated as per capita (*pc*) measures and as shares of 1970 GDP (*gdp*) to give a better indication of their relative importance. We also employ natural resource wealth data recently published by the World Bank (1997, 2005). The World Bank natural resource indicators value different components of natural wealth in USD per capita on the basis of the net present value of rents and are available for 1994 and 2000. We use the average measure over the two years available to minimize possible measurement errors and price fluctuations in the calculations.[7]

Figure 2.1 shows the ordinary least squares (OLS) regression fits of the World Bank resource abundance measures on economic growth between 1970-2000 (detailed basic estimation results can be found in the Appendix, Table 2.8). Clearly, there is no longer a negative association suggesting a curse of natural resource abundance: on the contrary, we now observe a significant *positive* relationship, especially when we consider the evidence for per capita subsoil wealth.

As a further illustration of how different measures of resource endowment can deliver radically different estimation results, we calculate the correlations between SW's measure of natural resource wealth at the beginning of the observation period, beginning-of-period mineral production data, and the World Bank indicators for total natural wealth and subsoil assets per capita. We can see from the results in Table 2.1 that *sxp* is positively correlated with mineral production per capita and weighed by GDP (column (1)), though correlations with absolute production amounts are consistently negative. However, primary export shares are clearly not correlated with the other measures of resource abundance, *natcap* and *subsoil*. On the other hand, the correlations between the World Bank indicators – per capita subsoil assets *subsoil* and

[7] Ding and Field (2005) made use of the total natural capital data for 1994, and Gylfason (2001) and Stijns (2006) employ slightly modified versions of the World Bank (1997) data. Natural resources valued by the World Bank in both its studies include subsoil assets (fuel and non-fuel minerals), timber resources, non-timber forest resources, protected areas, cropland, pastureland, and total natural capital. The partial indicators of forest and agricultural wealth gave no statistically significant results in the estimations and are therefore not shown.

Table 2.1: Correlations between natural resource wealth estimates

| | sxp | nonfuelmin | fuelmin | min | nonfuelminpc | fuelminpc | minpc | subsoil | natcap | nonfuelmin/gdp | fuelmin/gdp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| nonfuelmin | −0.20* | 1.00 | | | | | | | | | |
| | (−0.34*) | | | | | | | | | | |
| fuelmin | −0.06 | 0.85* | 1.00 | | | | | | | | |
| | (−0.13) | (0.47) | | | | | | | | | |
| min | −0.08 | 0.88* | 0.99* | 1.00 | | | | | | | |
| | (−0.14) | (0.78) | (0.96) | | | | | | | | |
| nonfuelminpc | 0.28* | 0.13 | 0.06 | −0.00 | 1.00 | | | | | | |
| | (−0.01) | (0.82) | (0.15) | (0.53) | | | | | | | |
| fuelminpc | 0.60* | −0.04 | 0.06 | 0.05 | −0.04 | 1.00 | | | | | |
| | (0.34*) | (0.23) | (0.71) | (0.62) | (0.28) | | | | | | |
| minpc | 0.54* | 0.02 | 0.07 | 0.08 | 0.12 | 0.99* | 1.00 | | | | |
| | (0.18*) | (0.67) | (0.60) | (0.8) | (0.75) | (0.93) | | | | | |
| subsoil | 0.05 | 0.19 | 0.07 | 0.12 | 0.37* | 0.54* | 0.58* | 1.00 | | | |
| | (0.02) | (0.41) | (0.21) | (0.45) | (0.4) | (0.44) | (0.60) | | | | |
| natcap | −0.01 | 0.28* | 0.1 | 0.16 | 0.30* | 0.42* | 0.49* | 0.74* | 1.00 | | |
| | (−0.12) | (0.27) | (0.08) | (0.25) | (0.3) | (0.36) | (0.37) | (0.73) | | | |
| nonfuelmin/gdp | 0.4* | 0.03 | 0.00 | −0.03 | 0.61* | 0.52* | 0.38* | 0.12 | −0.01 | 1.00 | |
| | (0.08) | (0.72) | (0.23) | (0.51) | (0.9) | (0.3) | (0.7) | (0.25) | (0.09) | | |
| fuelmin/gdp | 0.29* | 0.07 | 0.17 | 0.16 | 0.17 | 0.88* | 0.79* | 0.50* | 0.28* | 0.41* | 1.00 |
| | (0.09) | (0.34) | (0.79) | (0.68) | (0.19) | (0.87) | (0.69) | (0.39) | (0.14) | (0.35) | |
| min/gdp | 0.34* | 0.13 | 0.16 | 0.14 | 0.45* | 0.89* | 0.75* | 0.49* | 0.20* | 0.70* | 0.99* |
| | (0.02) | (0.75) | (0.69) | (0.8) | (0.73) | (0.77) | (0.89) | (0.49) | (0.16) | (0.79) | (0.91) |

*Notes*: * Pearson's correlation statistically significant at 10 percent level or less. Spearman's rho in parentheses. *sxp* measures primary exports over GDP in 1971 and is taken from SW. *subsoil* and *natcap* are averaged estimates for subsoil assets and total natural capital (in 1994 and 2000), respectively, and are taken from World Bank (1997, 2000). Mineral production data for 1970 is measured in tons and taken from IGS (1978) and British Petroleum database. For detailed variable descriptions and sources see the Appendix.

total natural capital *natcap* – and per capita mineral production and mineral production over GDP are consistently positive and highly significant.[8]

In our estimations, we will use the World Bank's per capita natural resource data to test their effect on economic growth over the period 1970-2000, and then compare the results with those reached using *sxp*. There are several reasons to choose the World Bank estimates over the production data as the most reliable measures of relative natural resource abundance currently available, and hence the best measures for testing the resource curse hypothesis. For one, data quality on mineral production for the early 1970s is not uniform; furthermore, unweighted production data are unsatisfactory proxies for natural resource wealth as they make no distinction between the value of different minerals.[9]

Mineral production is also more likely to be affected by the levels of technology (and economic development) in a country. This endogeneity is assumed to be less of a problem with the World Bank data, as they rely more on the Bank's own estimates as opposed to countries' sometimes questionable published statistics. Nevertheless, we cannot completely rule out endogeneity *a priori*, as simple correlation tests reveal that both natural resource measures correlate moderately but positively with income and schooling levels.[10] Much lower correlation coefficients for the mineral assets measure – which is of particular interest due to the previous literature – seem to suggest that mineral deposits have attracted substantial research effort regardless of their

[8] This also suggests that the countries' natural resource wealth, measured by their mineral abundance (subsoil assets) and total natural capital, has changed relatively little over the past three decades, confirming the hypothesis of Gylfason (2001).

[9] For example, one additional ton of sulphur has the same production effect as one additional ton of gold. Assigning weights to the minerals extracted is however equivalent to estimating their monetary value.

[10] The total natural resource measure has a correlation coefficient of 0.50 with end-of-period income levels and of 0.60 with average schooling, while mineral resources correlated by 0.32 and 0.34 with income and schooling levels, respectively. Results were significantly lower for beginning-of-period values of schooling and income.

location and consequently suffer less from endogeneity. However, we keep this issue in mind when performing the robustness tests in Section 2.3.3 in order check for a bias in the estimations. As a final point, the World Bank measures of natural resource wealth are deemed the best parallel to the economic wealth indicator of income per capita.

### 2.2.2 Natural resources and institutional quality

Several recent contributions have stressed the importance of institutional quality for economic development (e.g., Knack and Keefer, 1995; Mauro, 1995; Hall and Jones, 1999; La Porta et al., 1999; Acemoglu et al., 2001). But in quantitative work on the resource curse hypothesis, the institutional channel has seldom been verified with much success, although it has frequently been mentioned as an important potential cause of the curse. Institutional quality is often simply controlled for by using a measure of corruption (e.g., Sachs and Warner, 1995a; Papyrakis and Gerlagh, 2004). There are some notable exceptions: Bulte et al. (2005) find that natural resource abundance, and especially mineral resources, have an ambiguous direct effect on several measures of human development, and a slightly negative indirect effect via two measures of institutional quality. Mehlum et al. (2006) show that the interaction of natural resource abundance with high-quality institutions – measured by an aggregate indicator – has a positive growth effect, while the direct negative growth effect of resource wealth seems to persist. However, these results are based on resource exports data, which pose the problems already discussed above: we contend that they more accurately depict the effects of natural resource *exports dependence*.[11]

From a more qualitative angle, historians, political scientists, and economists generally agree that the presence of abundant natural resources (espe-

[11] Partly addressing this shortcoming, Boschini et al. (2004) supplement export data with production data and find evidence for a curse of highly "appropriable" resources, e.g. minerals, in countries with low-quality institutions.

cially minerals) leads to rent-seeking behavior and corruption, thereby decreasing the quality of government, which in turn negatively affects economic performance (e.g., Auty, 2001; Leite and Weidmann, 2002; Isham et al., 2005; Norman, 2006).[12] Robinson et al. (2006) develop a political economy model which shows that the impact of a "resource boom" crucially depends on the quality of the political institutions, and in particular the degree of clientelism in the public sector. Countries with worse-quality institutions are more likely to suffer from a resource curse. There is also evidence that natural resource abundance considerably increases the potential of violent civil conflict (Collier and Hoeffler, 2005). Empirically, rent-seeking due to natural resources has been shown to be non-linear, both with respect to income and the total amount of resources in a country. In his cross-country study, Ross (2001) finds that the negative resource effects of mineral abundance on institutions decline with increasing income levels and with greater past mineral exports. And in their case study of Nigeria, Sala-i-Martin and Subramanian (2003: 10) describe how "oil corrupts and excess oil corrupts more than excessively". They stress that the natural resource curse only holds for mineral – and particularly oil – abundance, and not agricultural products and food (all measured by their respective export shares).

In a different vein, Atkinson and Hamilton (2003) show that natural resource abundance may have negative effects on development when weak institutions allow resource profits to be spent in government consumption rather than investment, especially in countries with low levels of genuine saving. Stijns (2005) contends that there are both positive and negative channels through which natural resource abundance affects economic growth; he finds that land abundance tends to have negative effects on all determinants of growth, including different measures of institutional quality, while the effects of mineral abundance are less clear-cut. He concludes that "learning processes" are the crucial element in determining the direction of influence of

[12] For formal models of rent-seeking behavior, see Tornell and Lane (1999) and Torvik (2002).

resource wealth on growth, i.e. how countries exploit and develop their resources. Finally, Acemoglu et al. (2001) test the effects on current income levels of their instrumented indicator for institutions against those of natural resource abundance, measured by the country shares of world non-fuel mineral reserves and per-capita oil resources. They find no significant influence of natural resource abundance at all, confirming their view that institutional quality alone can explain a great deal of the cross-country differences in economic development, and implicitly questioning the natural resource curse hypothesis even further.

From the literature, it emerges that the growth and development effects of natural resource abundance are rather ambiguous when institutional quality is included in the analysis; there may in fact only be a curse when natural resource wealth occurs together with low-quality institutions. In this paper, we will explore this possibility by focusing both on natural resource abundance and on institutional quality. The most important institutional aspects in this context appear to be the rule of law and corruption, and the competence of the state and particularly the bureaucracy – aspects which are in fact connected. We show results for two different institutional quality indicators that cover these aspects, namely measures of the rule of law and government effectiveness (described below), and interact them with our resource abundance measures. In a second step we instrument for them to account for the possible endogeneity of the quality of institutions themselves, including the possibility that natural resource abundance negatively affects institutions.

Table 2.2: Descriptive statistics

| **Variable** | **Obs.** | **Mean** | **Std. Dev.** | **Min.** | **Max.** |
|---|---|---|---|---|---|
| Log growth of income per capita, average 1970-2000 (*g7000*) | 102 | 2.44 | 0.80 | −0.13 | 4.26 |
| Log total natural capital in US$ per capita, average 1994-2000 (*lnnatcap*) | 84 | 8.36 | 0.92 | 6.59 | 10.76 |
| Log subsoil wealth in US$ per capita, average 1994-2000 (*lnsubsoil*) | 63 | 5.76 | 2.41 | −0.69 | 10.46 |
| Primary exports / GDP in 1970 (*sxp*) | 114 | 0.16 | 0.16 | 0.01 | 0.89 |
| Rule of law, average 1996-2000 (*ruleoflaw*) | 158 | 2.54 | 1.0 | 0.67 | 4.74 |
| Government effectiveness, average 1996-2000 (*goveffect*) | 165 | 2.52 | 0.99 | 0.19 | 5.01 |

*Note:* Variable sources and detailed descriptions are given in the Appendix.

## 2.3 Natural resources, institutions, and growth: results of cross-country estimations

### 2.3.1 Data and descriptive statistics

Table 2.2 presents descriptive statistics for the key variables. Average growth of per capita income between 1970-2000 is PPP adjusted (detailed variable descriptions and sources are provided in the Appendix). This will be the dependent variable for the subsequent estimations. It is evident from the data that the growth differences in the sample of roughly 100 countries are quite large, with a standard deviation in log per capita income growth of 0.8. Rows 2-3 describe the logs of the natural resource abundance indicators introduced above, namely total natural capital and subsoil wealth per capita, respectively, averaged over 1994-2000. The differences in subsoil wealth between the countries in the sample are particularly remarkable, with a standard deviation of 2.39. SW's natural resource indicator *sxp* is described in row 4.

The last two rows show the main variables used to measure institutional quality, which are taken from a World Bank dataset covering different dimensions of governance from 1996 onwards (Kaufmann et al., 2005; also included in the *World Development Indicators*). The dataset comprises six "clustered" indicators, which are all positively correlated amongst each other, as well as with measures of institutional quality used in the growth literature (e.g., Knack and Keefer, 1995; La Porta et al., 1999; Acemoglu and Johnson, 2005).[13] The main advantages of the World Bank measures lie in their objectivity – provided by a very broad survey sample which includes and adds to the sources for earlier indicators – and the excellent country coverage.

The six indicators are roughly divided into three groups: the first looks at the selection and replacement process of those in authority (*voice and accountability* and *political stability and violence*); the second examines the state's ability to implement sound policies (*government effectiveness* and *regulatory burden*); and the final two indicators measure the respect of citizens and the state for rules and regulations (*rule of law* and *control of corruption*). We present results for one indicator each from the second and third group – the more relevant groups for our purposes – which closely resemble those used in other studies, and averaged them over 1996-2000. For space reasons, we do not present the findings for *control of corruption*; however, all regressions were also performed with this, as well as the other World Bank indicators with analogous results (available upon request). *ruleoflaw* measures the quality of contract enforcement, of the police and the courts, as well as the likelihood of crime and violence; *goveffect* measures the quality of the bureaucracy and of public services. Again, the data report a wide variety in the level of rule of law and government effectiveness between the countries, considering that the estimates range from zero to 5, with institutional quality increasing with the value of the indicator.

[13] Correlations with several other measures of institutional quality, including indicators for the beginning of the sample period are shown in the Appendix, Tables 2.9-2.10. They confirm the view that institutions have remained relatively stable over the last decades, and also diminishes the disadvantage of not having earlier data for our estimations.

### 2.3.2 Ordinary Least Squares regressions

To better compare the growth effects of different natural resource measures, we begin with standard cross-country OLS regressions of the type used in the resource curse literature. The idea is that (the log of) economic growth $G^i$ between t=1970 and T=2000 in country $i$ is a function of a vector of explanatory variables, including the natural logarithm of natural resource abundance $R^i$, and institutional quality $INST^i$.

Table 2.3 presents results of the linear regressions for[14]

$$G^i = \alpha_0 + \alpha_1 Y_{70}^i + \alpha_2 R^i + \alpha_3 INST^i + \alpha_4 Z^i + \epsilon^i \tag{2.1}$$

where $Y$ is the log of income per capita in 1970 (our basic control for the growth regressions, as in SW and subsequent estimations), $R$ and $INST$ are the natural resource abundance and institutional quality variables, respectively, $Z$ is a vector of other covariates, and $\epsilon$ is a random error term. Throughout the paper, we are particularly interested in the coefficient $\alpha_2$. Since we use logs, the effect of natural resource abundance on income growth is expressed as an elasticity.

Panel A in Table 2.3 shows the results of estimations using the rule of law as the main institutional indicator, while Panel B reports the results using government effectiveness. Column (1) shows a significant negative effect of natural resource abundance on growth when using the SW indicator *sxp*. Columns (2)-(4) show a weakly significant positive influence of natural resource abundance on growth when using total natural capital per capita, which disappears when we control for regional effects (Europe and Central Asia is the omitted region throughout the estimations). Columns (5)-(7) however show that an abundance of subsoil wealth has a consistent and highly significant *positive* effect on economic growth. All other things equal, the results would imply that an increase in per capita subsoil wealth would have

[14] The results of simple OLS regressions using only our natural resource variables *lnnatcap* and *lnsubsoil* and the SW variable *sxp* are presented in the Appendix, Table 2.8.

Table 2.3: OLS regressions: natural resources, institutions, and growth

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Panel A* | | | | | | | |
| lgdp70 | −0.32** | −0.62*** | −0.63*** | −0.75*** | −0.85*** | −0.86*** | −0.93*** |
| | (0.13) | (0.15) | (0.15) | (0.16) | (0.16) | (0.16) | (0.18) |
| sxp | −2.48*** | | | | | | |
| | (0.79) | | | | | | |
| lnnatcap | | 0.20** | 0.20** | 0.08 | | | |
| | | (0.10) | (0.10) | (0.09) | | | |
| lnsubsoil | | | | | 0.15*** | 0.16*** | 0.13*** |
| | | | | | (0.04) | (0.04) | (0.03) |
| ruleoflaw | 0.59*** | 0.73*** | 0.71*** | 0.69*** | 0.81*** | 0.69*** | 0.67*** |
| | (0.13) | (0.13) | (0.16) | (0.14) | (0.13) | (0.17) | (0.16) |
| latitude | -0.32 | | 0.11 | | | 0.77 | |
| | (0.58) | | (0.70) | | | (0.74) | |
| Africa&ME | | | | −0.85*** | | | −0.99*** |
| | | | | (0.28) | | | (0.27) |
| Asia&Ocean. | | | | 0.07 | | | -0.21 |
| | | | | (0.27) | | | (0.26) |
| N.Am. | | | | 0.21 | | | -0.12 |
| | | | | (0.37) | | | (0.35) |
| C.&S.Am. | | | | -0.05 | | | -0.37 |
| | | | | (0.27) | | | (0.3) |
| Adj.$R^2$ | 0.37 | 0.32 | 0.31 | 0.48 | 0.46 | 0.46 | 0.58 |
| N | 90 | 79 | 79 | 79 | 61 | 61 | 61 |
| *Panel B* | | | | | | | |
| lgdp70 | −0.32** | −0.59*** | −0.59*** | −0.68*** | −0.85*** | −0.87*** | −0.87*** |
| | (0.13) | (0.15) | (0.15) | (0.16) | (0.15) | (0.15) | (0.17) |
| sxp | −2.32*** | | | | | | |
| | (0.8) | | | | | | |
| lnnatcap | | 0.19* | 0.2* | 0.07 | | | |
| | | (0.10) | (0.10) | (0.1) | | | |
| lnsubsoil | | | | | 0.14*** | 0.15*** | 0.12*** |
| | | | | | (0.03) | (0.04) | (0.03) |
| goveffect | 0.56*** | 0.72*** | 0.68*** | 0.67*** | 0.86*** | 0.73*** | 0.67*** |
| | (0.13) | (0.13) | (0.17) | (0.15) | (0.13) | (0.17) | (0.16) |
| latitude | -0.1 | | 0.29 | | | 0.80 | |
| | (0.58) | | (0.72) | | | (0.69) | |
| Africa&ME | | | | −0.80*** | | | −0.89*** |
| | | | | (0.29) | | | (0.28) |
| Asia&Ocean. | | | | 0.16 | | | -0.11 |
| | | | | (0.27) | | | (0.25) |
| N.Am. | | | | 0.1 | | | -0.21 |
| | | | | (0.38) | | | (0.34) |
| C.&S.Am. | | | | −0.04 | | | -0.35 |
| | | | | (0.28) | | | (0.29) |
| Adj.$R^2$ | 0.37 | 0.29 | 0.28 | 0.45 | 0.49 | 0.49 | 0.59 |
| N | 89 | 79 | 79 | 79 | 61 | 61 | 61 |

*Notes*: Dependent variable is log income growth 1970-2000. Standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively. Joint significance tests strongly reject hypothesis of no difference between covariates in all estimations. For detailed variable descriptions and sources see the Appendix.

a fairly large positive growth effect if we were to assume a direct causality. On average, an increase by one standard deviation in dollarized per capita subsoil assets would have increased income growth over the period by up to $(2.41 * 0.16 =)$ 0.39. The corresponding beta coefficient of $0.39/0.80 = 0.48$ shows that a one-standard-deviation difference in mineral wealth corresponds to an average change in growth of nearly half a standard deviation. The findings suggest that the use of *sxp* as the preferred measure of natural resource abundance may have led to a negative bias in the literature.

In all estimations, the institutional quality indicators are positive and highly significant, confirming the view that "institutions matter". The coefficients for our rule-of-law and government-effectiveness measures suggest that an increase on the institutional quality index would have had a sizeable positive growth effect on average, again assuming a direct causal relationship.[15] The highly significant negative coefficients for initial income throughout the growth estimations are in accordance with the convergence literature.[16]

### OLS estimations with interaction terms

A question which naturally arises is how resource abundance and institutional quality interact. Although natural resources may have positive growth effects in general, the results so far could have been driven by resource-rich countries with high-quality institutions. To investigate this possibility, we insert an interaction term between our natural resource abundance and institutional quality measures in the basic regression equation 2.1 and again compare them with the SW primary exports ratio, *sxp*. Accordingly, the new estimation

[15] For example, for a one-standard-deviation improvement on the rule-of-law index we could have observed a *ceteris paribus* average growth increase of up to 0.73 over the period, corresponding to a beta coefficient of $(0.73/0.80 =)$ 0.91!

[16] As an interesting aside, latitude proves insignificant in our estimations, running counter to the hypothesis that geographical and climatic factors, determined by distance from the equator, have an important direct effect on economic growth (see also 2SLS regressions below).

Table 2.4: OLS regressions with interaction terms

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| lgdp70 | $-0.30^{**}$ | $-0.78^{***}$ | $-0.84^{***}$ | $-0.88^{***}$ | $-0.95^{***}$ | $-0.24^{*}$ | $-0.75^{***}$ | $-0.76^{***}$ | $-0.91^{***}$ | $-0.9^{***}$ |
| | (0.14) | (0.14) | (0.15) | (0.15) | (0.17) | (0.14) | (0.15) | (0.15) | (0.14) | (0.16) |
| sxp | $-5.95^{***}$ | | | | | $-5.59^{***}$ | | | | |
| | (2.39) | | | | | (2.29) | | | | |
| lnnatcap | | $1.25^{***}$ | $1.00^{***}$ | | | | $1.23^{***}$ | $0.96^{***}$ | | |
| | | (0.26) | (0.23) | | | | (0.29) | (0.26) | | |
| lnsubsoil | | | | $0.37^{***}$ | $0.37^{***}$ | | | | $0.36^{***}$ | $0.31^{***}$ |
| | | | | (0.08) | (0.07) | | | | (0.08) | (0.07) |
| ruleoflaw | $0.33^{*}$ | $3.66^{***}$ | $3.34^{***}$ | $1.26^{***}$ | $1.18^{***}$ | | | | | |
| | (0.18) | (0.7) | (0.63) | (0.25) | (0.24) | | | | | |
| goveffect | | | | | | $0.29^{*}$ | $3.64^{***}$ | $3.23^{***}$ | $1.34^{***}$ | $1.22^{***}$ |
| | | | | | | (0.17) | (0.79) | (0.72) | (0.25) | (0.25) |
| interaction | $1.53^{*}$ | $-0.33^{***}$ | $-0.3^{***}$ | $-0.08^{***}$ | $-0.07^{***}$ | $1.43^{*}$ | $-0.33^{***}$ | $-0.29^{***}$ | $-0.09^{***}$ | $-0.08^{***}$ |
| | (0.85) | (0.08) | (0.07) | (0.03) | (0.03) | (0.83) | (0.09) | (0.08) | (0.03) | (0.03) |
| latitude | | 0.55 | | 0.67 | | | 0.70 | | 0.75 | |
| | | (0.64) | | (0.7) | | | (0.67) | | (0.64) | |
| Africa&ME | $-0.22$ | | $-0.71^{***}$ | | $-0.85^{***}$ | $-0.2$ | | $-0.65^{**}$ | | $-0.74^{***}$ |
| | (0.28) | | (0.25) | | (0.26) | (0.29) | | (0.27) | | (0.26) |
| Asia&Ocean. | $0.48^{*}$ | | 0.15 | | $-0.15$ | 0.48 | | 0.28 | | $-0.03$ |
| | (0.26) | | (0.24) | | (0.24) | (0.26) | | (0.26) | | (0.24) |
| N.Am. | 0.04 | | 0.46 | | 0.14 | 0.04 | | 0.38 | | 0.09 |
| | (0.45) | | (0.34) | | (0.34) | (0.45) | | (0.36) | | (0.34) |
| C.&S.Am. | 0.14 | | $-0.05$ | | $-0.27$ | 0.14 | | $-0.03$ | | $-0.25$ |
| | (0.26) | | (0.24) | | (0.28) | (0.26) | | (0.26) | | (0.28) |
| Adj.$R^2$ | 0.44 | 0.45 | 0.58 | 0.53 | 0.63 | 0.43 | 0.4 | 0.54 | 0.56 | 0.64 |
| N | 90 | 79 | 79 | 61 | 61 | 89 | 79 | 79 | 61 | 61 |

*Notes*: Dependent variable is log income growth 1970-2000. Standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively. Joint significance tests strongly reject hypothesis of no difference between covariates in all estimations. For detailed variable descriptions and sources see the Appendix.

equation is:

$$G^i = \alpha_0 + \alpha_1 Y_{70}^i + \alpha_2 R^i + \alpha_3 INST^i + \alpha_4 R^i * INST^i + \alpha_5 Z^i + \epsilon^i \qquad (2.2)$$

where $\alpha_4$ denotes the coefficient of the interaction term. The results are shown in Table 2.4.

First, we note that the coefficients on our natural resource and institutional quality measures retain their expected signs; their significance in fact seems reinforced. But the interaction terms appear significantly negative throughout the estimations (columns (2)-(5) and (7)-(10)), suggesting that the *positive growth effects diminish as institutional quality improves*. And conversely, from columns (1) and (6) we see that higher institutional quality appears to reinforce the negative growth effects of the share of primary exports, confirming the findings of Mehlum et al. (2006). It is possible that natural resource wealth has boosted growth rates more in countries at lower levels of institutional development; the more highly developed the institutions, the weaker the positive growth impulses of natural resource abundance. This explanation is reminiscent of the convergence effect of income levels with respect to growth rates; and in fact institutional quality and income levels are highly positively correlated. Consequently, to test this "convergence effect" of natural resources with regards to institutions, we re-estimated the regressions allowing initial GDP per capita to interact with our resource abundance measures. The interaction terms again turned up with a negative sign, confirming that more institutionally and economically developed countries have on average experienced lower positive growth effects of resource wealth (results available upon request).

We can therefore explain the negative interaction coefficients in Table 2.4; but what of the positive findings on the growth effects of natural resource abundance found so far? In fact, our overall results do not change much with the interaction terms: natural resource abundance still has a significantly positive net influence on economic growth. To show this, we can calculate the total resource effects for interesting values of our institutional quality measures – as the coefficients in Table 2.4 correspond to an effect with zero, i.e. unrealistically bad, quality institutions. For example, using the results from column (2), we can take the sample mean of the quality of rule of law to obtain the average effect of a one-standard-deviation increase in natural resources per capita on a country's growth as $0.92*(1.25-(0.33*2.54)) = 0.38$. With other words, a one-standard-deviation change in natural resource wealth would increase economic growth by 0.38 from the mean. Similarly, from column (4) a one-standard-deviation increase in mineral resources gives us a positive total growth effect of $2.41*(0.37-(0.08*2.54)) = 0.40$. On the other hand, *sxp* still has negative overall growth effects, namely around $-0.33$ for a one-standard-deviation change in the share of resource exports (from column (1)).

However, it is possible that the institutional indicators in our OLS estimations suffer from endogeneity due to omitted variable effects. Indeed, if there is resource-induced rent-seeking behavior leading to corruption among government officials and less respect for the rule of law, as well as worse bureaucratic quality, then natural resource wealth itself may be negatively correlated with institutions and outweigh the positive direct growth influence. These factors are not sufficiently accounted for in OLS, which is why in the next subsection we use an appropriate instrument for institutional variation and also take into account the possible influence of resource wealth, and then perform two-stage least squares (2SLS) estimations.

### 2.3.3 Two-Stage Least Squares regressions

Equation 2.1 described the basic relationship between natural resource wealth and institutional quality on one side, and economic growth on the other. In addition we have

$$INST^i = \beta_0 + \beta_1 R^i + \beta_2 L^i + \beta_3 Z^i + \nu^i, \tag{2.3}$$

where $INST$ denotes the measure of institutional quality, now the dependent variable, $R$ is again the natural resource abundance measure, $Z$ is the vector of covariates affecting all variables, $\nu$ is the random error term, and $L$ is latitude (distance from equator calculated on a scale from 0 to 1), our main instrument for institutional quality.[17]

[17] We also considered a country's regime type, classified according to the Polity IV index of Marshall and Jaggers (2002), as an instrument for institutional quality, with similar results to those shown using latitude. However, the Polity measure was less robust to the inclusion of other variables, and – being a complex composite index – could suffer from measurement error and endogeneity issues. A further possible instrument for institutional quality is given by the data on settler mortality collected by Acemoglu et al. (2001). Using this instrument drastically reduced the sample size and the statistical quality of

Table 2.5: Determinants of institutions

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| latitude | 2.53*** | 4.09*** | 2.67*** | 4.30*** | 2.91*** | 2.61*** | 3.91*** | 2.59*** | 4.06*** | 2.72*** |
| | (0.37) | (0.36) | (0.40) | (0.35) | (0.42) | (0.35) | (0.34) | (0.38) | (0.35) | (0.42) |
| lnnatcap | | 0.26*** | 0.04 | | | | 0.27*** | 0.06 | | |
| | | (0.07) | (0.07) | | | | (0.07) | (0.07) | | |
| lnsubsoil | | | | 0.07** | 0.01 | | | | 0.08*** | 0.03 |
| | | | | (0.03) | (0.03) | | | | (0.03) | (0.03) |
| lgdp70 | | | 0.51*** | | 0.47*** | | | 0.47*** | | 0.45*** |
| | | | (0.09) | | (0.10) | | | (0.09) | | (0.10) |
| adjR | 0.22 | 0.71 | 0.79 | 0.74 | 0.81 | 0.25 | 0.71 | 0.79 | 0.73 | 0.79 |
| N | 158 | 84 | 84 | 63 | 63 | 165 | 84 | 84 | 63 | 63 |

*Notes*: All regressions are OLS. The dependent variable in columns (1)-(5) is *ruleoflaw*, and in columns (6)-(10) it is *goveffect*. Standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively. For detailed variable descriptions and sources see the Appendix.

There have been several studies on the link between latitude and economic development, but there is no widely accepted explanation for the observed correlation.[18] We follow Hall and Jones (1999) in assuming that the direct effect of a country's latitude on its economic performance is zero and that any observed influence appears only via the institutional channel. This assumption is strengthened by the observation that latitude becomes statistically insignificant in our OLS estimations once institutional quality is controlled for (see Tables 2.3-2.4).

Table 2.5 presents OLS regressions for equation 2.3. Columns (1) and (6) show that latitude alone accounts for up to one quarter of the variation in our institutional quality measures, and it remains highly significant when adding other covariates. Columns (2)-(5) and (7)-(10) show that natural resource abundance has a positive effect on institutional quality; the effect is however not robust to controlling for initial income, although the sign remains positive. Nevertheless, we believe that these findings cast some doubt on the rent-seeking explanation for the resource curse: we find that natural resource

the estimations, although the coefficients on the resource abundance indicators remained positive. Results are available upon request.

[18] See for example Gallup et al. (1999) and the debate on the importance of geography for economic development in Rodrik et al. (2004) and Sachs (2003).

abundance does not *necessarily* lead to worse institutions, and may even have a positive influence.[19]

Equations 2.1 and 2.3 form the basis for the two-stage least squares regressions presented in Table 2.6. Equation 2.3 is our first stage for the institutional quality measures, shown in Panel B; equation (1) is the second stage, shown in Panel A. The results confirm those found in the OLS regressions, both regarding the sign and the magnitude of the coefficients of interest. The broad measure of natural resource abundance, natural capital per capita, has a positive direct effect on economic growth in the period observed. But this effect practically disappears when we control for regions, suggesting that most of the positive growth effect of natural capital is limited to certain areas of the world. The results show that resource-rich African and Middle Eastern economies in particular have performed much worse than European and Central Asian ones. The indirect effect via the institutional channel is statistically even weaker.

Subsoil wealth, on the other hand, has a highly significant positive direct effect on growth, while the indirect effect is once more very weak. Again, this is especially interesting as much of the resource-and-growth literature has found highly significant *negative* growth effects of mineral resources, in particular. But our results consistently show that on average a one-standard-deviation increase in per capita subsoil wealth in a country would have directly increased average economic growth by up to $0.16 * 2.41 = 0.39$ over the period, all other things equal (beta coefficient 0.48). This closely corresponds to the previous findings in the simple OLS regressions.[20]

These results challenge the resource curse hypothesis: neither a broadly constructed measure of natural resource wealth, nor a narrower measure of

[19] We could also not find signs of rent-seeking using alternative institutional quality measures based on the level of corruption: estimations yielded the same significant positive effect of resource abundance on (the absence of) corruption (results available upon request).

[20] Adding the effect of the (statistically insignificant) indirect institutions channel gives us a growth impact of a one-standard-deviation change in mineral resources of up to 0.41.

Table 2.6: 2SLS regressions: natural resources, institutions, and growth

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| *Panel A* | | | | | | | | |
| *2SLS* | | | | | | | | |
| lnnatcap | 0.20** | 0.08 | | | 0.19* | 0.06 | | |
| | (0.10) | (0.09) | | | (0.10) | (0.1) | | |
| lnsubsoil | | | 0.16*** | 0.13*** | | | 0.14*** | 0.12*** |
| | | | (0.04) | (0.03) | | | (0.03) | (0.04) |
| ruleoflaw | 0.76*** | 0.69** | 0.96*** | 0.67* | | | | |
| | (0.21) | (0.32) | (0.19) | (0.34) | | | | |
| goveffect | | | | | 0.79*** | 0.8** | 1.04*** | 0.90** |
| | | | | | (0.22) | (0.38) | (0.21) | (0.43) |
| lgdp70 | −0.65*** | −0.75*** | −0.99*** | −0.9*** | −0.65*** | −0.77** | −1.02*** | −1.04*** |
| | (0.21) | (0.28) | (0.20) | (0.31) | (0.22) | (0.3) | (0.21) | (0.34) |
| Africa&ME | | −0.84*** | | −0.93*** | | −0.75** | | −0.75* |
| | | (0.31) | | (0.31) | | (0.34) | | (0.37) |
| Asia&Ocean. | | 0.07 | | −0.16 | | 0.17 | | −0.09 |
| | | (0.27) | | (0.26) | | (0.28) | | (0.26) |
| N.Am. | | 0.20 | | −0.11 | | 0.13 | | −0.12 |
| | | (0.40) | | (0.38) | | (0.4) | | (0.38) |
| C.&S.Am. | | −0.04 | | −0.27 | | 0.08 | | −0.09 |
| | | (0.39) | | (0.44) | | (0.45) | | (0.53) |
| *Panel B* | | | | | | | | |
| *1st stage* | | | | | | | | |
| latitude | 2.68*** | 1.98*** | 2.85*** | 1.93*** | 2.57*** | 1.72*** | 2.62*** | 1.53*** |
| | (0.4) | (0.48) | (0.42) | (0.47) | (0.38) | (0.47) | (0.42) | (0.51) |
| lnnatcap | 0.02 | 0.04 | | | 0.03 | 0.05 | | |
| | (0.07) | (0.07) | | | (0.07) | (0.07) | | |
| lnsubsoil | | | 0.01 | 0.02 | | | 0.02 | 0.03 |
| | | | (0.03) | (0.02) | | | (0.03) | (0.03) |
| lgdp70 | 0.51*** | 0.64*** | 0.50*** | 0.67*** | 0.49*** | 0.59*** | 0.49*** | 0.61*** |
| | (0.09) | (0.1) | (0.1) | (0.1) | (0.09) | (0.09) | (0.10) | (0.10) |
| Africa&ME | | −0.01 | | −0.03 | | −0.15 | | −0.26 |
| | | (0.23) | | (0.22) | | (0.23) | | (0.37) |
| Asia&Ocean. | | 0.32 | | 0.34* | | 0.13 | | 0.13 |
| | | (0.22) | | (0.2) | | (0.21) | | (0.22) |
| N.Am. | | −0.31 | | −0.31 | | −0.18 | | −0.21 |
| | | (0.28) | | (0.25) | | (0.27) | | (0.27) |
| C.&S.Am. | | −0.39* | | −0.51** | | −0.51** | | −0.64*** |
| | | (0.22) | | (0.23) | | (0.22) | | (0.24) |
| Adj.$R^2$ | 0.8 | 0.83 | 0.82 | 0.87 | 0.8 | 0.82 | 0.81 | 0.85 |
| N | 79 | 79 | 61 | 61 | 79 | 79 | 61 | 61 |

*Notes*: Dependent variable in 2SLS is log income growth 1970-2000; dependent variable in first stage is *ruleoflaw* in columns (1)-(4) and *goveffect* in columns (5)-(8). Standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively. For detailed variable descriptions and sources see the Appendix.

mineral wealth show a negative effect on economic growth. On the contrary, the empirical results point to a significant *positive effect of natural resource abundance*, especially for mineral resources, which is confirmed when we consider institutional quality and its possible endogeneity. In other words, natural resources – and particularly mineral resources – seem to have robust direct positive effects even when we explicitly control for institutional quality and possible interactions. We also find no conclusive evidence of a negative indirect growth effect of natural resource abundance via institutional quality, apparently contradicting the rent-seeking hypothesis.

Consistent with the hypothesis that "institutions matter", our institutional quality measures remain positive and significant even when accounting for endogeneity. In addition, the magnitude of the institutional effect remains largely unchanged with respect to the results of the simple OLS regressions reported in Table 2.3. The robustness of these overall results is investigated below.

**Robustness tests**

The validity of our results depends on the assumption that natural resource wealth has strong direct growth effects which are not due to omitted variable bias. We check the robustness of the findings by adding further control variables which have been found to influence economic growth in the literature.[21] The variables include ethnic fractionalisation on a scale from 0 to 1 (from Alesina et al., 2003); the log of initial population; the average years of schooling of adults age 15 and over between 1970-2000 (Barro and Lee, 2001); and the measure of economic openness developed by Sachs and Warner (1995b), which has been used extensively in the resource curse literature. An alternative measure of openness, defined as the GDP share of total trades (exports plus imports) between 1970-2000, yielded statistically more significant coefficients but had no effect on the natural resource indicators.

Other economic control variables included government consumption and investment as shares of GDP between 1970-2000; and the period averages of financial depth – i.e. the ratio of liquidity in an economy to its GDP

[21] See Easterly and Levine (1997) for an early application of this method of testing robustness.

– and foreign direct investment. Further social controls were measures of language and religious fractionalization; a dummy variable derived from the Polity IV database indicating whether a country experienced a regime transition or violent change between 1970-2000; legal origin dummies; and the average mortality between 1970-2000. Our results proved robust to all these additional variables, as well (for convenience, only a selection of controls is presented; full results are available upon request).

Overall, the estimations, reported in Table 2.7, show that our results change very little with the inclusion of these variables. The estimations for the broad natural resource measure, reported in columns (1)-(5), confirm that the influence is significantly positive, but not robust to all controls, in particular years of schooling (column (3)). However, the results using our measure of per capita subsoil wealth are very robust to all additional controls; the positive effect remains highly significant and essentially unchanged in its magnitude even when controlling for all other effects simultaneously (column (10)). Note in particular that the average level of schooling – as a proxy of the level of technology – does not alter the positive growth effects of mineral wealth. With other words, there does not seem to be a serious endogeneity problem with our measures of resource abundance related to the quality and amount of resource exploration in a given country. There is also no large-country bias: including initial population size does not change the findings for our resource estimates.

Our indicators of institutional quality, on the other hand, are no longer significant when including all control variables together, which is not surprising as there is probably some multicollinearity between the variables. Interestingly, not all of the variables emphasized in previous research prove significant in our estimations. Ethnic fractionalization has a significant negative effect on growth, confirming the results of Easterly and Levine (1997) and Alesina et al. (2003). Schooling has a significant positive growth effect (in the general natural capital estimations in columns (2) and (5)), as found in the human capital and growth literature. Population size also positively influences the

Table 2.7: 2SLS growth regressions with additional control variables

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| *Panel A 2SLS with ruleoflaw* | | | | | | | | | | |
| lnnatcap | $0.25^{**}$ | $0.20^{**}$ | 0.13 | $0.22^{**}$ | $0.21^{**}$ | | | | | |
| | (0.1) | (0.09) | (0.10) | (0.10) | (0.09) | | | | | |
| lnsubsoil | | | | | | $0.17^{***}$ | $0.14^{***}$ | $0.15^{***}$ | $0.16^{***}$ | $0.15^{***}$ |
| | | | | | | (0.03) | (0.03) | (0.04) | (0.04) | (0.04) |
| ruleoflaw | $0.46^{*}$ | $0.61^{***}$ | $0.6^{**}$ | $0.61^{**}$ | 0.06 | $0.71^{***}$ | $0.81^{***}$ | $0.92^{***}$ | $0.87^{***}$ | 0.45 |
| | (0.24) | (0.2) | (0.25) | (0.28) | (0.32) | (0.23) | (0.19) | (0.27) | (0.25) | (0.31) |
| lgdp70 | $-0.56^{***}$ | $-0.54^{***}$ | $-0.85^{***}$ | $-0.7^{**}$ | $-0.72^{***}$ | $-0.89^{***}$ | $-0.85^{***}$ | $-1.02^{***}$ | $-1.01^{***}$ | $-0.83^{***}$ |
| | (0.21) | (0.29) | (0.18) | (0.20) | (0.17) | (0.21) | (0.20) | (0.20) | (0.20) | (0.18) |
| ethnic fract. | $-1.07^{***}$ | | | | $-0.88^{**}$ | $-0.82^{**}$ | | | | $-0.68^{*}$ |
| | (0.39) | | | | (0.36) | (0.4) | | | | (0.37) |
| lpop70 | | $0.17^{***}$ | | | $0.12^{**}$ | | $0.16^{***}$ | | | $0.13^{***}$ |
| | | (0.05) | | | (0.05) | | (0.05) | | | (0.05) |
| schooling | | | $0.15^{**}$ | | $0.13^{*}$ | | | 0.03 | | 0.02 |
| | | | (0.07) | | (0.07) | | | (0.08) | | (0.07) |
| openness | | | | 0.57 | $0.76^{**}$ | | | | 0.32 | $0.53^{*}$ |
| | | | | (0.36) | (0.32) | | | | (0.32) | (0.29) |
| N | 79 | 79 | 75 | 77 | 73 | 61 | 61 | 59 | 61 | 59 |
| *Panel B 2SLS with goveffect* | | | | | | | | | | |
| lnnatcap | $0.25^{**}$ | $0.19^{**}$ | 0.12 | $0.21^{**}$ | $0.21^{**}$ | | | | | |
| | (0.1) | (0.1) | (0.10) | (0.10) | (0.09) | | | | | |
| lnsubsoil | | | | | | $0.16^{***}$ | $0.13^{***}$ | $0.13^{***}$ | $0.14^{***}$ | $0.14^{***}$ |
| | | | | | | (0.03) | (0.03) | (0.04) | (0.03) | (0.03) |
| goveffect | $0.45^{*}$ | $0.65^{***}$ | $0.59^{**}$ | $0.65^{**}$ | 0.06 | $0.75^{***}$ | $0.91^{***}$ | $0.97^{***}$ | $0.95^{***}$ | 0.47 |
| | (0.23) | (0.22) | (0.25) | (0.30) | (0.32) | (0.24) | (0.21) | (0.27) | (0.27) | (0.32) |
| lgdp70 | $-0.55^{***}$ | $-0.56^{***}$ | $-0.88^{***}$ | $-0.71^{***}$ | $-0.73^{***}$ | $-0.90^{***}$ | $-0.9^{***}$ | $-1.02^{***}$ | $-1.03^{***}$ | $-0.74^{**}$ |
| | (0.21) | (0.21) | (0.19) | (0.21) | (0.19) | (0.21) | (0.22) | (0.2) | (0.20) | (0.18) |
| ethnic frac. | $-1.02^{***}$ | | | | $-0.89^{***}$ | $-0.88^{**}$ | | | | $-0.74^{**}$ |
| | (0.35) | | | | (0.32) | (0.37) | | | | (0.34) |
| lpop70 | | $0.15^{***}$ | | | $0.18^{**}$ | | $0.13^{**}$ | | | $0.12^{**}$ |
| | | (0.05) | | | (0.05) | | (0.05) | | | (0.05) |
| schooling | | | $0.17^{**}$ | | $0.13^{**}$ | | | 0.03 | | 0.03 |
| | | | (0.07) | | (0.06) | | | (0.08) | | (0.07) |
| openness | | | | 0.58 | $0.76^{**}$ | | | | 0.3 | $0.53^{*}$ |
| | | | | (0.36) | (0.31) | | | | (0.32) | (0.28) |
| N | 79 | 79 | 75 | 77 | 73 | 61 | 61 | 59 | 61 | 59 |

*Notes*: Dependent variable in 2SLS is log income growth 1970-2000. First stage regressions for institutional variables are not shown to save space. Standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively. For detailed variable descriptions and sources see the Appendix.

average growth over the period. The measure for economic openness, however, is only significantly related to economic growth when controlling for all effects simultaneously. In the first-stage regressions (not shown), our main instrument for institutional quality – latitude – consistently remained highly significant, while the natural resources measures again had no significant effect on institutions.

## 2.4 Conclusions

This paper re-examines two main aspects of the resource curse literature, namely the widespread use of Sachs and Warner's (1995a) measure of resource abundance based on primary export data, and the limited attention paid to institutional quality in growth with natural resources. Using recently-developed measures of resource abundance which estimate natural capital in USD per capita, as well as indicators of institutional quality, we find new cross-country evidence which challenges the resource curse hypothesis.

Results from both OLS and 2SLS estimations contradict most of the resource curse literature so far, showing that natural resources, and in particular mineral resources, have a positive direct association with real GDP growth over the period 1970-2000, even when controlling for the quality of institutions. In addition, there is no evidence that resource abundance negatively affects institutional quality, contradicting the hypothesis of an indirect natural resource curse, e.g. through rent-seeking behavior. Interestingly however, the beneficial growth effects seem to diminish as institutional quality improves, although they remain strongly positive overall. The results are robust to controlling through additional variables.

In sum, an abundance of natural resources may in fact be much less of a curse and more of a boon for economic performance than often believed. This conclusion suggests a different perspective on the growth effects of natural resources over the last thirty years and is also relevant from a policymaking perspective. While advancing particular policy suggestions is beyond the scope of this paper, more caution should be applied before making gloomy predictions for resource-rich countries and suggesting that resources had better be left untouched to avoid adverse development impacts. Further research is needed to analyze normative aspects, including more case studies of how resource-rich countries have developed their natural wealth to supplement the findings of large cross-country studies. Also, the attempts to model the influence of natural resource abundance on economic growth have so far not proven wholly satisfactory; in addition to the possibility that resources may have positive instead of the usually assumed negative growth effects, a theoretical explanation would surely have to include the role of institutions in the growth process.

## 2.5 Appendix

Table 2.8: Basic OLS regressions of natural resource abundance on growth

| | SW (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| lgdp70 | 0.4* | | | | 0.14* | 0.04 | -0.05 |
| | (0.22) | | | | (0.08) | (0.12) | (0.12) |
| sxp | −6.92*** | −3.39*** | | | −3.16*** | | |
| | (2.11) | (0.83) | | | (0.83) | | |
| lnnatcap | | | 0.20** | | | 0.18 | |
| | | | (0.09) | | | (0.12) | |
| lnsubsoil | | | | 0.12*** | | | 0.13*** |
| | | | | (0.04) | | | (0.05) |
| Adj.$R^2$ | 0.13 | 0.15 | 0.05 | 0.12 | 0.17 | 0.04 | 0.11 |
| N | 97 | 90 | 79 | 61 | 90 | 79 | 61 |

*Notes*: Column (1) reports the basic result of Sachs and Warner (1995a) with log of per capita GDP growth between 1970-1989 as the dependent variable. In columns (2)-(7) the dependent variable is log of per capita GDP growth from 1970-2000. Results shown using SW's measure *sxp*, as well as logs of World Bank indicators of subsoil and total natural capital (1994-2000 averages). Standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 2.9: Correlations between institutional quality measures: rule of law

| | ruleoflaw | GLprights70 | GLprights7000 | Hprights95 | Hprights9500 |
|---|---|---|---|---|---|
| ruleoflaw | 1.00 (158) | | | | |
| GLprights70 | 0.8 (48) | 1.00 (48) | | | |
| GLprights7000 | 0.84 (118) | 0.92 (48) | 1.00 (118) | | |
| Hprights95 | −0.8 (95) | −0.63 (38) | −0.7 (84) | 1.00 (96) | |
| Hprights9500 | −0.86 (151) | −0.67 (48) | −0.69 (116) | 0.93 (95) | 1.00 (153) |

*Notes*: Number of observations in parentheses. All results are statistically significant at the 1-percent level. *ruleoflaw* denotes average 1996-2000 World Bank measure of the rule of law. *GLprights70* and *GLprights7000* are measures of the legal system quality and property rights enforcement in 1970 and averaged over 1970-2000, respectively, taken from the dataset compiled by Gwartney and Lawson (2005). They are measured on a scale of 0 (no legal system and property rights in place or enforced) to 10 (very well-developed legal system and fully enforced property rights). *Hprights95* and *Hprights9500* are measures for property right enforcement for 1995 (first available year) and averaged over 1995-2000, respectively. They are measured on a scale from 1 (fully enforced) to 5 (no enforcement) and are taken from the Heritage Foundation dataset (Holmes et al., 2006).

Table 2.10: Correlations between institutional quality measures: government effectiveness

| | goveffect | burdelay | corrupt |
|---|---|---|---|
| goveffect | 1.00 (165) | | |
| burdelay | 0.85 (58) | 1.00 (58) | |
| corrupt | 0.76 (118) | 0.85 (54) | 1.00 (118) |

*Notes*: Number of observations in parentheses. All results are statistically significant at the 1-percent level. *goveffect* denotes average 1996-2000 World Bank measure of government effectiveness. *burdelay* is a measure of bureaucratic delays (average 1972-1995), scaled from 0 to 10 with low ratings indicating higher levels of red tape (less effectiveness). *corrupt* is an indicator of government corruption, scaled from 0 to 10 with low ratings indicating more corrupt government officials. The latter indicators are taken from the dataset compiled by La Porta et al. (1999).

Table 2.11: Natural resource measures by country

| Country | Subsoil wealth | Tot. natural capital | Country | Subsoil wealth | Tot. natural capital |
|---|---|---|---|---|---|
| Argentina | 1886.5 | 10081.0 | Korea, South | 41.5 | 2480.0 |
| Australia | 10285.5 | 29753.5 | Lesotho | | 727.5 |
| Austria | 357.5 | 7372.0 | Madagascar | | 4095.5 |
| Bangladesh | 51.5 | 2035.5 | Malawi | | 832.5 |
| Benin | 12.5 | 1631.5 | Malaysia | 5076.0 | 10461.5 |
| Bolivia | 787.0 | 5421.5 | Mali | | 3498.5 |
| Botswana | 408.0 | 4401.5 | Mauritania | 4041.0 | |
| Brazil | 1309.0 | 6906.0 | Mauritius | | 941.0 |
| Burkina Faso | | 1809.5 | Mexico | 4967.5 | 7561.5 |
| Burundi | 2.0 | 1575.9 | Morocco | 93.0 | 1907.0 |
| Cameroon | 627.0 | 5766.5 | Mozambique | 0.00 | 1094.5 |
| Canada | 12658.0 | 35680.5 | Namibia | 953.0 | 4766.0 |
| Chad | | 3705.5 | Nepal | 5.0 | 2064.5 |
| Chile | | 12692.0 | Netherlands | 2151.5 | 5439.5 |
| China | 465.5 | 2446.5 | New Zealand | 2448.0 | 47158.0 |
| Colombia | 2193.0 | 6323.5 | Nicaragua | 4.5 | 2891.0 |
| Congo, Rep. of | 4248.0 | 6875.0 | Niger | 0.5 | 7157.5 |
| Costa Rica | | 8193.5 | Norway | 34964.5 | 42524.0 |
| Côte d'Ivoire | 16.0 | 3455.5 | Pakistan | 207.5 | 1624.0 |
| Denmark | 2716.5 | 11408.0 | Panama | | 5675.5 |
| Dominican Rep. | 193.0 | 5778.0 | Paraguay | | 6181.0 |
| Ecuador | 3587.5 | 12223.5 | Peru | 682.0 | 4102.5 |
| Egypt | 937.0 | 2818.0 | Philippines | 55.0 | 2139.5 |
| El Salvador | | 1031.0 | Portugal | 115.5 | 3834.5 |
| Finland | 84.0 | 13687.5 | Rwanda | | 1588.0 |
| France | 73.5 | 7227.5 | Senegal | 32.0 | 3286.0 |
| Gambia, The | | 1317.0 | South Africa | 1229.0 | 3800.0 |
| Germany | 309.5 | 4297.5 | Spain | 95.0 | 5057.0 |
| Ghana | 37.5 | 1628.0 | Sri Lanka | 0.0 | 2148.5 |
| Greece | 319.0 | 4882.0 | Sweden | 336.5 | 11270.0 |
| Guatemala | 180.5 | 2345.5 | Trinidad&Tobago | 19794.5 | 21543.5 |
| Guinea-Bissau | | 4914.0 | Switzerland | 0.0 | 4496.5 |
| Haiti | 0.0 | 816.5 | Thailand | 274.5 | 5768.0 |
| Honduras | 62.0 | 3192.5 | Togo | 63.5 | 1792.5 |
| India | 205.5 | 2919.0 | Tunisia | 1160.0 | 5154.5 |
| Indonesia | 1109.5 | 5476.0 | Turkey | 195.0 | 3722.0 |
| Ireland | 457.5 | 14157.0 | United Kingdom | 2734.5 | 6053.5 |
| Italy | 260.5 | 4039.0 | United States | 5143.0 | 15626.0 |
| Jamaica | 1743.0 | 2853.5 | Uruguay | | 12044.5 |
| Japan | 34.0 | 1906.5 | Venezuela | 19131 | 24023.5 |
| Jordan | 154.5 | 975.5 | Zambia | 247.0 | 3634.5 |
| Kenya | 0.5 | 1549.00 | Zimbabwe | 235.5 | 2025.5 |

*Notes*: Main World Bank (1997, 2005) natural resource abundance variables used in estimations, measured in USD per capita. 1994-2000 averages shown; variables used and listed only for countries for which data were available in both years.

Table 2.12: Variables and sources

| Variable | Definition | Source |
|---|---|---|
| g7000 | Log of growth of real GDP per capita between 1970-2000, PPP adjusted. | PWT 6.1 |
| natcap | Log of the average total natural capital in 1994 and 2000, estimated in USD per capita. The measure includes subsoil assets, timber resources, non-timber forest resources, protected areas, cropland, and pastureland. | World Bank (1997, 2005) |
| subsoil | Log of the average subsoil assets in 1994 and 2000, estimated in USD per capita. The measure includes energy resources (oil, natural gas, hard coal, lignite) and other mineral resources (bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin, zinc). | World Bank (1997, 2005) |
| nonfuelmin | Aggregate production in tonnes of 52 non-fuel minerals, ranging from aluminium to zirconium. With the exception of a few countries where series started in 1971-1974, data is for 1970. Variables used in estimations include total tonnes, tonnes per capita, and weighted by real GDP. | IGS |
| fuelmin | Aggregate production in tonnes of coal, petroleum, and natural gas. With the exception of a few countries where coal and petroleum series started in 1971-1974, data is for 1970. Variables used in estimations include total tonnes, tonnes per capita, and weighted by real GDP. | IGS and BP |
| min | nonfuelmin+fuelmin | IGS and BP |
| sxp | Primary exports over GDP in 1971. | SW |
| ruleoflaw | Measures the average score of the quality of contract enforcement, the police and the courts, as well as the likelihood of crime and violence between 1996-2000. Recalibrated to assume values between zero (worst) and 5 (best). | Kaufmann et al. (2005) |
| goveffect | Measures the average score of the quality of the bureaucracy and of public services between 1996-200. Recalibrated to assume values between zero (worst) and 5 (best). | Kaufmann et al. (2005) |
| lgdp70 | Log of real GDP per capita in 1970. | PWT 6.1 |
| latitude | Absolute value of latitude of a country on a scale of 0 to 1. | La Porta et al. (1999) |
| polity70 | Political regime measure ranging from $-10$ (institutionalised autocracy) to 10 (institutionalised democracy). Transition periods are smoothed, anarchy is assigned score 0, and foreign "interruption" is treated as missing data. Score of 1970. | Marshall and Jaggers (2002) |
| ethnic fractionalisation | Measure of ethnic fractionalisation ranging from 0 (least fractionalised) to 1 (extremely fractionalised) based on racial or linguistic characteristics, determined country-by-country. Most data for mid-1990s. | Alesina et al. (2003) |
| lpop70 | Population in 1970 (logs). | PWT 6.1 |
| schooling | Average years of schooling of population 15 years and over between 1970-2000. | Barro and Lee (2001) |
| openness | Measure of openness, defined as the fraction of years during period 1965-1990 in which the country is rated as an open economy according to set criteria. | Sachs and Warner (1995b) |

# Chapter 3

# The resource curse revisited and revised: a tale of paradoxes and red herrings*

We critically evaluate the empirical basis for the so-called resource curse and find that, despite the topic's popularity in economics and political science research, this apparent paradox may be a red herring. The most commonly used measure of 'resource abundance' can be more usefully interpreted as a proxy for 'resource dependence'-endogenous to underlying structural factors. In multiple estimations that combine resource abundance and dependence, institutional and constitutional variables, we find that (i) resource abundance, constitutions and institutions determine resource dependence, (ii) resource dependence does not affect growth, and (iii) resource abundance positively affects growth and institutional quality.

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## 3.1 Introduction

Inspired by work of Sachs and Warner (1995a), a new literature has developed that focuses on the so-called “resource curse” – the puzzling paradox suggesting that resource-rich countries tend to grow more slowly than resource-poor ones. Like most people, economists are fond of paradoxes. It is therefore not surprising that the curse has inspired many economists to consider its origins or test its robustness. Among the popular early explanations for the curse are ’structuralist’ theories with roots in the 1950s (e.g., Prebisch, 1950), rent-seeking analyses (e.g., Torvik, 2002), and stories based on Dutch-disease type of arguments, where the non-resource sector is the long-run engine of growth due to increasing returns at the sector level but becomes “crowded out” by the resource sector (e.g., Matsuyama, 1992).[1]

The rough contours of a consensus view now seem to be gaining shape. In the words of a recent World Bank publication (Harford and Klein, 2005):

> “[Natural resource exports] can damage institutions (including governance and the legal system) indirectly – by removing incentives to reform, improve infrastructure, or even establish a well-functioning tax bureaucracy – as well as directly – by provoking a fight to control resource rents. [...] There is growing evidence that [this] effect is the most problematic.”

Empirical support for this view is provided by various authors, including Ross (2001), Bulte et al. (2005), and Isham et al. (2005).[2] While resource abundance can be a blessing for countries with good institutions and a curse

[1] See also Wright and Czelusta (2004) for a critical assessment of the claim that the resource sector is unlikely to yield spillover benefits.

[2] This is not to argue that there are no “dissident” views: Manzano and Rigobon (2001) focus their analysis on debt overhang, Papyrakis and Gerlagh (2004) focus on the role of investments, Gylfason (2001) and Bravo-Ortega and De Gregorio (2005) on the role of human capital, and Hausmann and Rigobon (2002) on having a diversified export structure.

for countries with bad institutions (as demonstrated by Mehlum et al., 2006), the new consensus view goes one step further. It argues that the institutional context itself is endogenous and not invariant with respect to resource endowments (see also Sokoloff and Engerman, 2000; Jensen and Wantchekon, 2004; Robinson et al., 2006).[3] While the exact definition of "institutional quality" is open to debate, most economists agree that it refers to the rules of the game, and that it is an important driver of economic development and growth (e.g., Rodrik et al., 2004).

In this paper we re-examine the consensus view that abundant resources lead to bad institutions or slow growth. We argue instead that causality may run the other way: that bad institutions are associated with high scores on a resource abundance indicator such as that popularized by Sachs and Warner. To appreciate our argument, it is important to understand that the common proxy for resource abundance in the literature on the curse is rather peculiar. It is defined as the ratio of resource exports to GDP, generally based on the information for a single year at the beginning of the observation period.[4] This ratio is more appropriately thought of as a measure of dependence (or intensity) than as a measure of abundance. The denominator explicitly measures the magnitude of other activities in the economy. Consequently, the scaling exercise – dividing by the size of the economy – implies that the ratio vari-

[3] In a model by Hodler (2006), the link from resources to institutional deterioration is via conflict. For other work on the link between resources and conflict, refer to Collier and Hoeffler (1998) and others.

[4] Several authors have used alternative measures of resource abundance, casting some doubts on the consistency and robustness of the curse. Results of Atkinson and Hamilton (2003) and Gylfason (2001) suggest that the overall growth curse remains, although Boschini et al. (2004) confine it to countries with bad institutions. Brunnschweiler (2008) finds no curse evidence using World Bank resource data; Alexeev and Conrad (2005) employ several measures of resource abundance, including hydrocarbon deposits per capita, and oil and mining outputs, and find no negative effects on income; while Stijns (2005) considers several physical reserves and finds that the curse disappears for resources other than land – a result which in turn is challenged by Norman (2006).

able is not independent of economic policies and the institutions that produce them. Moreover, not only the scale of economic activity, but also the comparative advantage in non-resource sectors is to a large extent determined by government choices (Clarida and Findlay, 1992). Hence, the resource dependence ratio potentially suffers from endogeneity problems, and perhaps should not be treated as an exogenous explanatory variable at all in growth regressions (Wright and Czelusta, 2004). A better measure of resource abundance would reflect resource stocks, as opposed to current economic flows derived from them, and we examine several stock-based measures in this paper.

We distinguish between two different perspectives on institutions. Some analysts interpret institutions as "deep and durable" characteristics of societies (Glaeser et al., 2004), whereas others view them as the reflection of policy outcomes that are in a state of flux (Rodrik et al., 2004). The former interpretation is consistent with the idea of institutions as persistent constitutional variables – think of presidential systems versus parliamentary ones, or the specification of electoral rules. Within the framework of constitutional design, policy makers formulate specific short-term "governance" policies to fight corruption, uphold the rule of law, invest in human capital for public servants, etc. Constitutional design therefore determines a range of policy outcomes – institutional proxies and otherwise (Persson and Tabellini, hereafter PT, 2003, 2004). Evidently, the interpretation of institutions as policy outcomes is more likely to suffer from endogeneity problems in the context of growth regressions.

Both the "durable constraints" and the "changeable policy outcome" interpretations of institutions are potentially relevant for the resource curse. PT (2003, 2004) have pioneered the notion that constitutional designs have observable consequences on economic policies. Key concepts in their analysis are accountability and representativeness of a country's executive body. They find that both presidential regimes and majoritarian electoral rules (as opposed to parliamentarian systems and proportional representation) tend to be associated with more spending for special interests, at the expense of public goods that benefit a wider swathe of voters (and that could enhance economic growth). The reason is that presidential regimes and majoritarian rules imply that the incumbent decision-maker is not dependent on a stable majority among the legislators, and is therefore more likely to cater to the interests of powerful minorities (for more information, refer to Persson et al., 2000). In the context of the resource curse, one may therefore expect that sectoral lobbying for preferential treatment is more successful in presidential than in parliamentary systems. Indeed, an analysis based on the Sachs-Warner ratio of resource exports as a share of GDP suggests the "curse" is more likely to materialize in presidential regimes and in non-democracies (Andersen and Aslaksen, 2006).

The objectives of this paper are threefold. First, we explore the underlying factors that determine resource dependence and institutional quality, and properly account for them in Two-stage Least Squares (2SLS) and Three-stage Least Squares (3SLS) regression analyses of economic growth. Second, we explore the impact of an alternative and exogenous measure of resource abundance on economic growth and institutional quality. And third, we aim to dig deeper into the institutional dimensions of policy making by distinguishing between "durable" and "changeable" interpretations of institutions – i.e., how constitutional variables and institutional outcomes interact to give rise to virtuous or vicious circles of development.

Our main results seem to turn received wisdom upside down. Concentrating on mineral resources, we find that, first, resource dependence, based on a conventional Sachs-Warner "resource" measure in regression analyses, is influenced both by durable and changeable institutions, even if we control for physical resource abundance. Treating resource dependence as endogenous, we can reverse the causality implied in earlier work. Contrary to the paradoxical result that resource "abundant" countries tend to invite rent seeking and therefore suffer from worse institutions, we find that countries with certain institutional designs may fail to industrialize – and failing to develop significant non-resource sectors may make them dependent on primary sector extraction. This is an argument made previously by Wright and Czelusta (2004), and our results provide statistical support for it. Second, within the set of constitutional variables, we find that the form of government (presidential versus parliamentary system) is more relevant than the form of the electoral system. We interpret this as evidence that sectoral lobbying pressure from resource firms is more relevant for policy design than electoral pressure through geographically defined constituencies. We present evidence for this interpretation by distinguishing between different types of resources – clustered ones versus diffuse ones. Third, and perhaps most importantly, we find that the resource curse may be a red herring. Properly accounting for resource wealth implies that resources can be a blessing for both institutional and economic development – not a curse. Moreover, instrumenting for resource dependence implies that this variable is no longer significant in growth regressions.

## 3.2 Estimation strategy and data

In this section, we outline our empirical procedure and present the most important data. Our aim is to explore the underlying factors that determine the degree to which economies depend on exports of natural resources, and analyze the impacts of resource abundance and dependence on economic performance and institutional quality. Resource abundance may directly affect economic growth; but the influence may also be indirect, either through the level of resource dependence or via possible institutional impacts. Our empirical approach allows us to examine both direct and indirect links.

We run three different regression equations. Following earlier work (Isham et al., 2005; Bulte et al., 2005), we first perform a series of estimations to analyze whether resource abundance ($RA$) does in fact have the commonly reported negative effect on institutional quality ($I$). Specifically, we try to unravel the determinants of institutional quality as follows:

$$I = a_0 + a_1 * conditioningvariables + a_2 * RA + e. \tag{3.1}$$

Our main conditioning variables include latitude measured in absolute terms – a common instrument for institutions[5] – and regional dummy variables, as well as resource dependence ($RD$) in some specifications to check for a curse on institutions in a more conventional form. In light of earlier evidence, we distinguish between different "types" of resources: point resources, which are geographically clustered in space and relatively easy to monitor and control, versus diffuse resources spread across space. If resources are a curse for institutional quality, as has been argued in the past based on studies regressing $I$ on $RD$ as opposed to $RA$, then $a_2 < 0$. But if resource abundance is positively associated with institutions – due to an income effect, say – then $a_2 > 0$. The term "resource curse" would be inappropriate then.

In a second step, we study the association between RD on the one hand, and RA as well as "durable" and "changeable" institutional factors on the other. As outlined above, we distinguish between the "durable" constitutional dummy-variables for regime type and electoral rules ($CV$),[6] and the "changeable" indicators for institutions or institutional quality ($I$). In other words, we explore whether RD is an exogenous variable, as implicitly assumed in earlier work, or not. Our reduced-form "dependence equation" is specified as follows:

$$RD = b_0 + b_1 * conditioningvariables + b_2 * RA + b_3 * CV + b_4 * I + e, \tag{3.2}$$

[5] All relevant estimations were also run with other frequent instruments for institutions, including the log of settler mortality Acemoglu et al. (2001) and the fractions of the population speaking English or another Western European language. We focus on the results using latitude (our strongest instrument); results using the other instruments are very similar and available on request.

[6] We consider two indicator variables. The first assigns a value of one to any country that has a presidential regime. The second assigns a value of one to any country that uses majoritarian electoral rules.

where our main conditioning variables are historic openness averaged over 1950-1969 – which is expected to positively affect resource export shares – and regional dummies. There are several reasons why we believe $RD$ may be best treated as an endogenous variable. Obviously, it is likely to be positively influenced by resource abundance due to comparative advantage arguments (which is also why most conventional regression analyses treat the former as a proxy for the latter). But institutions may also matter, because they influence policy-making and (indirectly) affect incentives to invest and develop industrial or formal services sectors and thereby reduce the dependence on resources. Therefore, we expect $b_2, b_3 > 0$ and $b_4 < 0$.[7] In an additional step, we integrate the findings from equation 3.1 by endogenizing the changeable indicators for institutional quality $I$ in a 2SLS procedure.

Finally, we test for the presence of a direct effect of $RA$ on economic growth ($G$), i.e., effects not transmitted through either $I$ or $RD$:

$$G = c_0 + c_1 * RD + c_2 * I + c_3 * RA + c_4 * conditioningvariables + e, \quad (3.3)$$

where $RD$ and $I$ are estimated using 3.2 and 3.1, respectively. Equation 3.3 reflects that resource abundance may potentially have an impact on economic performance measures through three channels: indirectly via resource dependence or institutional quality, and directly as an asset that may be traded. It will be interesting to see if resource dependence, i.e. the conventional resource variable in resource curse papers, is still significant if we treat it as endogenous.

Next, we introduce the various data and their sources that we will use to estimate equations 3.1 - 3.3. Table 3.1 shows the descriptive statistics of the main dependent variables and instruments for resource dependence. The first column covers our base sample of some 60 countries from five regions (Europe, North America, Central and South America, Africa and the Middle East, Asia

[7] The two dummy variables for constitutional design, $CV$, assign values of one to countries which have a presidential regime vs. a parliamentary one, and to those which have majoritarian vs. proportional electoral rules.

Table 3.1: Descriptive statistics of main variables

| | Base sample | | Large sample | |
|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. |
| Average income growth 1970-2000 ($g7000$) | 2.457 | 0.813 | 2.398 | 0.802 |
| Average natural resource exports over GDP 1970-1980 ($natxp$) | 0.073 | 0.095 | 0.065 | 0.089 |
| Average mineral resource exports over GDP 1970-1980 ($minxp$) | 0.059 | 0.093 | 0.05 | 0.087 |
| Log of total natural capital in USD per capita ($lnatcap$) | 8.547 | 0.860 | 8.517 | 0.863 |
| Log of subsoil assets in USD per capita ($lsubsoil$) | 5.82 | 1.857 | – | – |
| Presidential regime dummy for the 1970s ($pres70s$) | 0.576 | 0.498 | 0.642 | 0.482 |
| Majoritarian electoral rules dummy for the 1970s ($maj70s$) | 0.5 | 0.505 | 0.530 | 0.503 |
| Rule of law ($rule$) | 2.81 | 1.069 | 2.729 | 1.026 |
| Government effectiveness ($goveffect$) | 2.875 | 1.07 | 2.753 | 1.035 |
| Average openness 1950-1960 ($open5060s$) | 0.434 | 0.237 | 0.442 | 0.233 |

*Notes*: Base sample for mineral dependence includes: Argentina, Australia, Austria, Bangladesh, Belgium, Benin, Bolivia, Brazil, Cameroon, Canada, China, Colombia, Rep. of Congo, Côte d'Ivoire, Denmark, Dominican Republic, Ecuador, Egypt, Finland, France, Ghana, Greece, Guatemala, Honduras, India, Indonesia, Ireland, Italy, Jamaica, Japan, Jordan, Korea, Malaysia, Mauritania, Mexico, Morocco, Nepal, Netherlands, New Zealand, Norway, Pakistan, Peru, Philippines, Portugal, Senegal, Sierra Leone, South Africa, Spain, Sweden, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, United Kingdom, United States, Venezuela, Zambia, Zimbabwe. In addition, the large sample for total natural resources includes: Burkina Faso, Burundi, Central African Republic, Chad, Chile, Costa Rica, El Salvador, The Gambia, Guinea-Bissau, Haiti, Kenya, Madagascar, Malawi, Mali, Mauritius, Nicaragua, Niger, Panama, Paraguay, Sri Lanka, Switzerland, Uruguay. Variable sources and detailed descriptions are given in the Appendix, Table 3.15.

and Oceania) for which we have data on mineral resource abundance and export shares.[8] Given the particular importance of point-source resources for institutional and economic development found in the literature, this will constitute our preferred sample. The second column depicts the descriptive statistics for the larger sample, covering total resource abundance and export shares in over 80 countries. In general, our variables show little variation between the two samples.

The first row depicts the log of average growth of per capita GDP (PPP adjusted) between 1970-2000 (*g7000*). Korea was the growth leader during this period in both samples, while Zambia was at the very bottom of the growth ladder.

Our main resource dependence variables, the GDP shares of total natu-

[8] Former Soviet and most Middle Eastern countries are excluded due to data unavailability.

ral resource and mineral resource exports – akin to the Sachs and Warner "resource abundance" variable – are described in rows 3-4. They are compiled on the basis of information from the World Development Indicators and aggregate the export share of total natural resources (*natxp*), i.e. the sum of mineral and agricultural raw material exports over GDP, and the export shares of mineral ores, metals and fuels (*minxp*), respectively. We average the shares over the period 1970-1989, because choosing a single year could lead to spurious links and false conclusions since exports are inevitably influenced by market conditions (see e.g., Ledermann and Maloney, 2003). In addition, the 1970s saw unusually large turbulence in many resource prices due to external shocks, which suggests using a longer time span.[9] Total natural resource dependence in our base sample and larger sample varies from GDP shares of practically zero for Japan and Mauritius to over 0.4 in the cases of Trinidad and Tobago and Zambia. Similarly, Nepal and Burkina Faso have exported next to no mineral resources relative to their GDP, while Trinidad and Tobago and Zambia again top the list with a GDP share of over 0.4. In Figure 3.1 we plot economic growth against resource dependence for a simple regression fit – controlling only for initial income and the change in terms of trade – confirming that the "curse" also materializes for our dataset (detailed results given in Table 3.4, column (1)).[10]

The next two rows show our preferred natural resource abundance measures, the logs of total natural capital and mineral resource assets in USD per capita. The data is taken from a World Bank (1997) study on countries' nat-

[9] Moreover we feel that working with average resource dependence over the period 1970-1989 better captures the idea that dependence may be endogenously determined, affected by other variables in the 1970s. However, we performed all estimations with alternative period averages for resource dependence (1970s and 1970-2000) with qualitatively unchanged results. For example, if we just base our dependence variable on 1970 resource exports (as SW did), then the main results are unaffected (details are available from the authors on request).

[10] The curse result is even stronger when we omit the outliers on the far right (t-ratio becomes $-2.79$, significant at the one-percent level).


Figure 3.1: GDP share of mineral exports and income growth

ural resource wealth and is estimated for the year 1994. The measure for total natural capital aggregates the estimates for subsoil assets, cropland, pastureland, timber and non-timber forest resources, and protected areas; the subsoil wealth measure values the principal fuel and non-fuel mineral stocks present in a country. All estimates are based on valuations of the net present value of benefits over a time horizon of 20-25 years (see World Bank, 1997 for further details). The richest countries in terms of overall resources turn out to be Australia, Canada, New Zealand and Norway, while Venezuela and Norway have the most subsoil assets relative to their population. Jordan and Malawi have the least total natural resources; and Belgium, Benin, Ghana, and Nepal share the bottom of the scale as regards subsoil wealth. Relying on data for the 1990s implicitly assumes that cumulative resource extraction since the 1970s has not significantly altered countries' relative resource abundance two decades later (Gylfason, 2001). This is supported by a high positive correlation with resource production data for the early 1970s: the countries which produced the most at the beginning of our observation period still had the richest resource stocks in the 1990s (Stijns, 2005; Brunnschweiler, 2008).[11]

A second issue concerns the exogeneity of our resource wealth measures. We argue that the commonly used resource variable of Sachs and Warner is endogenous, but do our variables offer an improvement? The accuracy and reliability of the country data were important concerns for the authors of the World Bank (1997) study; nevertheless, one could object that basic data availability is already subject to a country's technological level. However, the data on natural resource wealth are likely to be relatively independent of local issues, and therefore sufficiently exogenous for our purpose. In particular, we contend that the (fuel and non-fuel) mineral deposits which determine our core sample have been quite well explored and estimated due to their substantial economic potential, and thanks also to the involvement of large multinational firms who use similar technical approaches to gather their information, and do so regardless of the local political or technological conditions.[12] We are not suggesting that our resource abundance data are beyond criticism: the present value of rents is not completely invariant with respect to policies

[11] In the Appendix, Table 3.6 we show how various "abundance" measures discussed in this paper are correlated. For example, the correlation between our abundance variables and the primary exports to GNP ratio sxp from Sachs and Warner (1997) is 0.28 for subsoil assets, and 0.12 for total natural resource wealth.

[12] Around 90% of known oil and gas stocks are controlled by national companies, but "...because of the enormous capital and technological resources necessary to exploit minerals, foreign oil companies became the dominant internal actors in all oil exporters [...] The complexities of the international market, the continued need for foreign investment and technology, and their links to other powerful actors mean that these companies still retain significant power even after nationalization." (Karl, 1997, p.55) Moreover, foreign mineral companies have been known to get involved in production even if local political and regulatory conditions were unstable or deteriorated to the point of open conflict. An example is Shell's long-standing involvement in oil production in Nigeria despite violent conflict, and its willingness to enter into arrangements with both warring parties to ensure some level of production continuity (Zalik, 2004). Nevertheless, a counterfactual is lacking and we don't know to what extent these companies would have been involved in a different political setting.

(Bohn and Deacon, 2000). Rather, we believe they are less prone to the policy endogeneity which plagues export-based measures; less subject to technology standards which influence production levels; and only reasonably affected by price fluctuations (and market conditions), which must be an issue for any measure that attempts to assign a "true" (i.e. monetary) value to natural resource wealth. Despite their obvious shortcomings (such as a relatively limited sample coverage), these data probably offer some of the most interesting and high-quality estimates of resource abundance currently available. Nevertheless, we perform all estimations using a variety of alternative measures to confirm that our results are robust to different specifications.

As described above, we use two variables for the constitutional design, i.e. the fundamental and durable institutional characteristics, at the beginning of the period, depicted in rows 7-8. They are based on the classification of the Database of Political Institutions (DPI) compiled by Beck et al. (2005), and supplemented with data from PT (2004). As not all countries are coded starting in 1970, we use the first available entry for the 1970s.[13] The DPI codes a country's form of government as "presidential" ($pres70s = 1$) when the chief executive is largely independent of the legislature. This is true both when the president is directly elected by popular vote (as in the "classical" presidential model); or when the chief executive is elected by the assembly, but cannot easily be recalled once in office and therefore is mostly independent *vis-à-vis* the other branches of the political system. The alternative is a strictly parliamentary form of government ($pres70s = 0$). This definition corresponds to that of PT (2004, 2005); nevertheless, the classifications for the relevant years differ for three countries in our sample, namely Greece, Nepal, and Portugal. In these cases, we preferred the DPI coding, as it is more careful in indicating the true balance of power in the executive.

Regarding the electoral rule, a country is considered "majoritarian" ($maj70s = 1$) when all or the majority of the house seats are elected by

[13] In a few cases, the form of government changed during the decade; we use the later classification, as it is more likely to be important for development until 2000.

plurality rule, the alternative being (mostly) proportional rule ($maj70s = 0$). This DPI definition differs slightly from that of PT (2004, 2005), who consider a country's electoral rule to be majoritarian only if all house seats are elected by plurality, adding a third, "mixed" possibility to the classification. The country coding accordingly diverges for two countries in our sample, Japan and Mexico. Again, we follow the definition of the DPI in conflicting cases. Looking at the data, we see that the samples are divided roughly according to the global prevalence of presidential over parliamentary political regimes, and the closer balance between majoritarian and proportional electoral formulas. We can consequently avoid a possible sample bias in our estimations.

The next two rows in Table 3.1 describe our main measures of "changeable" institutional quality. They were compiled by Kaufmann et al. (2005) for the World Bank and measure the rule of law (*rule*), i.e. the quality of contract enforcement, police, and courts, as well as the likelihood of crime and violence; and what we dub government effectiveness (*goveffect*), i.e. the quality of the bureaucracy and public services. Both are recalibrated to assume values between 0 (weakest institutions) and 5 (strongest). The World Bank data have the advantages of a very wide country coverage and relative objectiveness thanks to a large survey base, which makes them particularly attractive for econometric analysis.[14] The differences between the samples are only slight, while the variation within the samples (the standard deviation is

[14] We performed robustness checks using several alternative institutional quality measures, including the remaining Kaufmann et al. (2005) variables (e.g. corruption control, voice and accountability). As these data begin in 1996, we also compared results using measures for earlier time periods, namely the measure of the quality of the legal system and property rights enforcement for the 1970s from the Fraser Institute's *Freedom of the World* database, and the measure of rule of law for 1982 compiled by Political Risk Services, taken from Sachs and Warner (1997). Correlations between the four measures were very high (0.8 and more), suggesting that institutions in our country sample have undergone only limited qualitative change over the last three decades. The estimation results with alternative institutional measures further confirm our main observations on the effects of natural resource abundance and dependence.

just above unity) shows that there are considerable differences in institutional quality among the countries in our survey. The Republic of Congo has the weakest and Norway the strongest institutions in our base sample, while Haiti exhibits the weakest institutions and Switzerland the strongest in the larger sample.

Finally, the last row describes our historic openness indicator for the two decades preceding our observation period, which serves as another principal instrument for explaining resource dependence in our estimations. It is calculated as the average ratio of imports plus exports to GDP between 1950-1969 to avoid endogeneity problems.[15] The data shows that there is wide variation in openness to trade in our samples, with a standard deviation of around 0.24.

## 3.3 Empirical results

We first analyze the determinants of institutions according to equation 3.1. In the most parsimonious specification, we use latitude as the main instrument for institutional quality and add natural resource abundance to explore whether resource wealth erodes institutional quality, be it through rent-seeking, conflict, or otherwise. The results, controlling for region-specific effects (Europe is the omitted region throughout the paper), are reported in Table 3.2, columns (1)-(4). They show that, quite contrary to earlier work on the resource curse – which argues that resources undermine economic performance through weakening of institutional structures – there is a *positive* correlation between resource *abundance* and institutional quality. Possibly this reflects the income effects of resource booms and discoveries, enabling countries to introduce superior institutions, while at the same time increas-

[15] The possible endogeneity of the openness measure was considered in separate estimations by using the predicted trade shares developed by Frankel and Romer (1999) as an instrument. Results were not affected.

Table 3.2: Institutional quality and natural resources

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | rule | rule | goveffect | goveffect | rule | rule | goveffect | goveffect |
| latitude | 2.519*** | 2.972*** | 2.706*** | 2.374*** | 2.631*** | 2.887*** | 2.486*** | 2.171*** |
| | (0.554) | (0.669) | (0.53) | (0.671) | (0.57) | (0.63) | (0.53) | (0.63) |
| lnatcap | 0.215*** | | 0.209** | | 0.194* | | 0.208** | |
| | (0.081) | | (0.082) | | (0.100) | | (0.093) | |
| lsubsoil | | 0.109** | | 0.097** | | 0.110** | | 0.132** |
| | | (0.041) | | (0.045) | | (0.051) | | (0.052) |
| natxp | | | | | 0.150 | | −0.098 | |
| | | | | | (0.67) | | (0.66) | |
| minxp | | | | | | −0.194 | | −1.145 |
| | | | | | | (0.69) | | (0.72) |
| Observations | 89 | 63 | 89 | 63 | 83 | 61 | 83 | 61 |
| F-stat | 58.49*** | 55.24*** | 56.16*** | 43.73*** | 48.54*** | 49.04*** | 44.50*** | 37.61*** |
| $R^2$ | 0.71 | 0.77 | 0.76 | 0.76 | 0.72 | 0.78 | 0.76 | 0.77 |

*Notes*: All regressions are OLS. Regional dummy variables included in all specifications. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

ing the demand for such improvements.[16]

To check if resource *dependence* has an impact on institutional quality, as postulated by advocates of the resource curse consensus, we also add the aggregate resource and mineral resource dependence variables to the analysis in columns (5)-(8). Although it mostly enters with a negative sign, resource dependence proves insignificant once we control for actual resource abundance.

We now consider whether the ratio of resource exports to GDP is a proper

[16] There are several plausible mechanisms linking higher incomes to better economic and political institutions: institutional quality as conventionally measured in economic studies is a policy choice (affected by human capital and income) (Glaeser et al., 2004); income shocks affecting real wages of civil servants may affect the willingness to accept bribes (Chand and Moene, 1999; Mookherjee, 1997) or have an impact on morale (both corruption and quality of the bureaucracy are conventional measures of institutional quality); or adverse income shocks can increase the risk of civil conflict, which in turn affects institutional quality (Miguel et al., 2004). While it does not explicitly consider institutional development, the model in Findlay and Lundahl (2001) could be interpreted that way.

explanatory variable in growth regressions. Since the denominator of this dependence measure is the size of the economy, it seems reasonable to expect that the variable is endogenous with respect to various variables that determine economic performance. We "explain" resource dependence with our indicators for institutions and add the two constitutional variables. Insofar as institutional quality and certain constitutional designs are associated with high incomes and growth-enhancing economic policies, we expect them to be negatively correlated with resource dependence.

In Table 3.3 we present the results of equation 3.2 and explore whether our prior expectation is correct, controlling for resource abundance and several other variables. In the various columns we distinguish between different types of resource dependence. Earlier work suggests that "point resources" have a different impact on the economy than "diffuse resources" (Bulte et al., 2005; Isham et al 2005). Columns (1) and (2) interpret resource dependence quite broadly so that it encompasses all types of primary exports; columns (3) and (4) focus on agricultural exports; and columns (5) - (8) present results for the narrower category of mineral resources. Consistent with earlier results, we find significant differences between mineral and agricultural exports, which in turn determine the findings for aggregate resource exports. The results are especially strong for the dependence on mineral resources, as is evident from the values for R-square and the highly significant F-statistics; they clearly indicate that resource dependence is greatly influenced by many "deep" variables of economies. This suggests that using resource dependence as an exogenous variable could produce misleading or biased outcomes, and makes an instrumental variables (IV) approach more suitable.[17]

First consider mineral resource dependence, as presented in columns (5) - (8), for which we find significant and robust results. Consistent with our

[17] Ding and Field (2005) also consider the endogeneity of resource dependence. However, their dependence measure is based on the share of natural capital in total capital, which less closely resembles the commonly used exports measures, and furthermore focus on the role of human capital for resource dependence and economic growth.

Table 3.3: Resource dependence, constitutions and institutions

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | natxp | natxp | agrixp | agrixp | minxp | minxp | minxp | minxp | minxp | minxp | minxp | minxp |
| pres70s | 0.043** | 0.060*** | −0.004 | 0.004 | 0.063*** | 0.059*** | 0.05** | 0.052** | 0.051* | 0.052** | 0.037 | 0.040* |
| | (0.020) | (0.020) | 0.005 | (0.0044) | (0.022) | (0.018) | (0.024) | (0.024) | (0.026) | (0.026) | (0.025) | (0.024) |
| maj70s | 0.024 | 0.034* | 0.005 | −0.005 | 0.027 | | 0.023 | 0.021 | 0.023 | 0.021 | | |
| | (0.017) | (0.018) | (0.005) | (0.005) | (0.019) | | (0.025) | (0.025) | (0.025) | (0.025) | | |
| lsubsoil | | 0.016*** | | | 0.016*** | 0.016*** | 0.021*** | 0.022*** | 0.021*** | 0.023*** | 0.020*** | 0.022*** |
| | | (0.004) | | | (0.005) | (0.004) | (0.006) | (0.006) | (0.006) | (0.007) | (0.005) | (0.006) |
| lnatcap | 0.038*** | | 0.007* | 0.006* | | | | | | | | |
| | (0.01) | | (0.004) | (0.0031) | | | | | | | | |
| open5060s | 0.205*** | 0.272*** | 0.014 | 0.023 | 0.247*** | 0.241*** | 0.259*** | 0.257*** | 0.258*** | 0.258*** | 0.251*** | 0.247*** |
| | (0.064) | (0.057) | (0.015) | (0.018) | (0.067) | (0.059) | (0.070) | (0.068) | (0.072) | (0.067) | (0.066) | (0.061) |
| rule | | | −0.004 | | | | −0.035** | | −0.031 | | −0.036* | |
| | | | (0.003) | | | | (0.014) | | (0.023) | | (0.020) | |
| goveffect | | | | | | | | −0.038** | | −0.040 | | −0.044* |
| | | | | | | | | (0.016) | | (0.029) | | (0.024) |
| Obs | 66 | 52 | 66 | 66 | 52 | 59 | 52 | 52 | 52 | 52 | 59 | 59 |
| Estimation meth. | OLS | OLS | OLS | OLS | OLS | OLS | OLS | OLS | 2SLS | 2SLS | 2SLS | 2SLS |
| Regional controls | no | no | no | yes | no | no | yes | yes | yes | yes | yes | yes |
| F-stat | 4.16*** | 9.06*** | 0.87 | 0.93 | 6.66*** | 9.81*** | 3.37*** | 3.48*** | | | | |
| $R^2$ | 0.37 | 0.59 | 0.09 | 0.18 | 0.53 | 0.53 | 0.58 | 0.58 | | | | |

*Notes*: Only second-stage results shown for the 2SLS in columns (9)-(10), where institutional quality is instrumented with latitude. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

expectations, we find that the presidential regime dummy is positively correlated with mineral resource dependence, and remains significant at least at the 5%-level even when we control for regions and institutional quality. The results suggest that having a presidential instead of a parliamentary system would have increased mineral resource dependence during this period by up to six percentage points. On the other hand, there is practically never any significant correlation between electoral rules and dependence. Indeed, in column (6) we see that omitting the majoritarian dummy does not affect results for our other explanatory variables, so we do not include this variable in subsequent regressions.[18] Since both majority rule and presidential systems are associated with a tendency to cater to interest groups and minorities (PT, 2004), our findings suggest that sectoral lobbies (from resource industries) tend to be more successful in pursuing distorting policies than geographic lobbies (working through constituencies). Moreover, openness and resource abundance are positively correlated with resource dependence.

In columns (7) and (8) we introduce two important institutional variables-rule of law and government effectiveness. These will constitute our basic specifications for later estimations. Not only are the earlier results robust; equally interesting, we find that the institutions variables enter with a significant negative sign (at the 2%-level). This suggests that better-quality institutions lead to less resource dependence, as opposed to the other way around. Even when we instrument for institutional quality to account for the probable endogeneity of this variable; as in the results reported in columns (9)-(12), we find that the negative relation persists. While the coefficients have the right sign, they are only significant at the 17% level when we also include the (weak) "majoritarian" dummy. However, when we remove this variable, both institutional variables are again significant at the 10% level (columns (11) and (12)).[19]

[18] All regressions were performed both with and without the weak majoritarian instrument, with the main change lying in the magnitude of the F-statistics.

[19] All our main results are robust to including ethnic fractionalization, foreign direct

Columns (3) and (4) indicate that dependence on agriculture is not adequately explained by the same variables. The goodness of fit of these regressions is much worse, and our presidential dummy is no longer significant. We believe this is due to the "diffuse nature" of agriculture, making it harder for farmers in developing countries to organize themselves into lobby groups and successfully appeal for special favors. The institutional quality variables also (narrowly) miss conventional levels of significance, although the sign is consistently negative. Not surprisingly, we find that natural capital – which also captures soil quality – is significantly associated with exports of agricultural products. However, in separate estimations we find that sheer country size is in fact more important than the value of the land in explaining the dependence on agricultural exports.

As shown in columns (1) and (2), aggregating the effects of point-source mineral resource and diffuse agricultural resource dependence allows us to account for a large part of total natural resource dependence using some common explanatory variables. But the results in column (2) indicate the strength of our explanation for total resource dependence is due in large part to the importance of minerals in overall exports: the values for R-square and the F-statistic jump upward when we use subsoil wealth as the resource abundance proxy. However, the differing factors which explain the extent of mineral and non-mineral resource dependence weaken each other's effect on total resource dependence, and the results are no longer robust to regional controls, nor is institutional quality robustly linked to resource dependence.

Taken together, the results in Tables 3.2 and 3.3 describe the net effect of resource abundance on resource dependence. On the one hand there is a direct effect based on the comparative advantage argument (captured in Table 3.3). On the other, resource abundance also enhances institutional quality (Table 3.2), which in turn translates into reduced dependence on primary exports of

investment, the average GDP shares of investment and government consumption, initial income, average schooling levels, distance to navigable port, and country size as alternative regressors.

minerals, (Table 3.3). However, our estimations show that the comparative-advantage effect dominates the indirect institutions effect. For example, a one-standard-deviation increase in a country's per-capita subsoil wealth would lead to an expected average increase in mineral resource dependence of one-third of a standard deviation.[20] The less-than-proportional impact of resource abundance on the degree of resource dependence would further confirm our hypothesis that the traditional resource dependence variable is only a weak proxy for true resource abundance.

A possible objection to our interpretation is that the results so far are mainly due to the circumstances in non-democratic and authoritarian developing countries, which are also considered presidential in the dummy classification. Such countries may also have weaker economic performance and worse policies per se, and therefore bias the results in favor of our hypotheses (e.g., Przeworski and Limongi, 1993). However, when we remove any country that scored above "5" on the 1972 Gastil index (the earliest available) compiled by Freedom House from our sample and re-run the estimations, we find that our earlier conclusions are largely unchanged.[21]

[20] From column (7) in Table 3.3 and column (2) in Table 3.2, the change is $1.857 * (0.109 * (-0.035) + 0.021) = 0.032$. The effect of mineral abundance on dependence in terms of standard deviations is then is $0.032/0.093 = 0.344$. Estimates from 2SLS with endogenous institutions deliver very similar results.

[21] Specifically, democratic countries with presidential regimes or low institutional quality are more resource dependent, although the influence of one type of political regime over the other is less clear-cut. We also find that resource abundance has a positive impact on resource dependence and institutional quality. However, the indirect effect of resource abundance on dependence via institutions is strengthened relative to the direct, comparative-advantage effect. Although comparative advantage prevails and the net effect remains positive, the impact is weaker, a result which is confirmed in 2SLS estimations where we again endogenize the institutional variable. One interpretation is that countries with better-developed institutions (such as democracies) have economies that are less biased towards lower-growth sectors (such as natural resource extraction and export) irrespective of their relative resource abundance. We also found that countries with a presidential regime tended to have worse-quality institutions, an effect which persisted in the democracies-only sample; see the Appendix for details. Similar results were obtained using

Table 3.4: Mineral dependence, institutional design, and growth impacts

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| minxp7080s | −6.59** | −4.612 | −3.568 | −3.263 | 0.507 |
| | (3.36) | (3.97) | (3.96) | (3.58) | (4.01) |
| lsubsoil | | 0.353*** | 0.317*** | 0.314** | 0.160 |
| | | (0.13) | (0.13) | (0.13) | (0.20) |
| rule | | 1.545*** | | 2.006* | |
| | | (0.41) | | (1.02) | |
| goveffect | | | 1.165*** | | 3.636 |
| | | | (0.41) | | (2.26) |
| lgdp70 | 0.127 | −2.023*** | −1.622*** | −2.385*** | −3.433** |
| | (0.21) | (0.40) | (0.41) | (0.82) | (1.57) |
| Endog. var. | | minxp | minxp | rule | goveffect |
| Obs | 59 | 58 | 58 | 59 | 59 |
| F-stat | 6.47*** | 4.00*** | 4.84*** | 108.08*** | 96.65*** |
| Excl. F-stat | | 6.54 | 8.16*** | | |
| Hansen J | | 0.22 | 0.42 | | |
| Shea partial $R^2$ | | 0.43 | 0.46 | | |
| 1st stage $R^2$ | 0.27 | 0.61 | 0.65 | 0.9 | 0.88 |

*Notes*: Dependent variable is (log) economic growth 1970-2000. Regression (1) reproduces a simple OLS specification from the curse literature with the additional basic control variable of change in terms of trade 1970-1998, which has a coefficient of 0.538 and r.s.e. 0.13 (source: Neumayer 2004). Regressions (2)-(5) are 2SLS with regional dummy variables included in all second-stage specifications. Only second-stage results shown; *pres70s* and *open5060s* are exogenous instruments for mineral resource dependence; *latitude* is the exogenous instrument for institutions. The *p*-values of the Hansen J statistic refer to the overidentification test that the instruments in the first-stage regressions do not enter the second-stage economic development equations. Constant term included in all regressions. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

We now turn to our main results. In column (1) of Table 3.4, we show OLS results for a growth regression of the type popular in the resource curse literature (corresponding to the regression fit in Figure 3.1), in order to test whether our findings depend merely on our narrower sample. We still find a significant curse result for our dependence measure, even when using a less parsimonious specification. We can therefore concentrate on the outcomes of the 2SLS regressions reported in the following columns, where we regress per capita income growth between 1970-2000 on the endogenous variables resource dependence and institutional quality. Only second-stage coefficients

different classifications of democracies, e.g. according to the Polity IV project.

are shown.

In columns (2)-(5) we provide the basic estimation results when instrumenting for resource dependence to correct for omitted variables, measurement errors and reverse causality. The first noteworthy result is that there is no significant association between resource dependence and income growth – although the sign is negative, the conventional "curse" ceases to exist. But our analysis seems to redeem resources to an even greater extent: the resource abundance variable mostly enters positively and significantly in the second stage estimations, so that the cumulative net effect on average growth is positive.[22] Moreover, in additional estimations limited to democracies only (see the Appendix), we show that the political and economic mechanisms linking resources to economic performance are not driven by idiosyncracies of dictatorships. We believe these results lend credibility to earlier ideas advanced by Davis (1995, 1998) – ideas that got snowed under in recent years by the emphasis on the detrimental effects of resources on growth and peace. Note that the Hansen J statistics imply that constitutional design and our openness-to-trade variable have no significant direct effect on economic growth (but influence it via their impact on the degree of resource dependence). While this does not dispute that alternative measures of "openness" may matter directly for growth, this result shows average historic openness over the 1950s and 1960s is an appropriate instrument for mineral dependence in first stage regressions.[23]

After having established that institutional quality is not invariant with respect to some of the deep economic and political variables, we also instrument for our two institutional proxies: *Government Effectiveness* and *Rule*

[22] For example, summing the effects from the two stages reported in column (2) yields a rough estimate of the average resource effect on growth: $0.015 * (-4.612) + 0.353 = 0.284$. This corresponds to an effect of $(0.284 * 1.857)/1.774 = 0.297$ in terms of standard deviations.

[23] The empirical evidence from the large literature on trade and growth remains mixed. Rodrik (2001, p. 24) argues that "the only systematic relationship is that countries dismantle trade barriers as they get richer."

*of Law.* These 2SLS results are provided in columns (4)-(5). Consistent with previous results, we find that that the resource dependence variable does not enter significantly, and even becomes positive when considering the quality of the bureaucracy (column (5)). Resource abundance still positively affects institutions in the first stage of the IV analysis; however, we now find weaker evidence of a direct effect on income growth. This suggests that the indirect institutional effect of resource abundance as shown in Table 3.3 is perhaps the main link from resources to economic performance. Nevertheless, the consistently positive signs show that natural resources have the potential to be a blessing for economic growth, not a curse. Institutions themselves enter the growth regression positively but not very significantly. Once again, similar results are found in the democracy sample (see the Appendix).

Our final set of results are based on an estimation of the full system of equations 3.1-3.3 described in Section 3.2, simultaneously instrumenting for both resource dependence and institutions. If the disturbances for the three equations are correlated, using a 3SLS approach will produce efficient estimates (Greene, 2003). In this analysis we aim to trace back the chain of causal relationships all the way to exogenous variables (resource abundance, constitutional variables, and latitude), but it is evident that this comes at a cost. The first and second-stage F-statistic is a useful summary statistic for assessing the potential bias in the second stage (the inverse of the F-statistic is proportional to the bias in the second stage). From the earlier tables it is evident that in particular instrumenting for resource dependence may introduce some bias, and the 3SLS analysis shown in Table 3.5 compounds that bias by regressing dependence on the predicted institutions variable. The main culprit for what must be a cautious statistical inference at this stage appears to be our small sample size, which in turn is due to the limited number of countries for which we have resource abundance data.

Notwithstanding these qualifications and caveats, the results in Table 3.5 support the earlier findings. In columns (1)-(2) we present results using the now familiar World Bank abundance variable. All signs are as expected,

Table 3.5: Mineral dependence, constitutions and institutions, and their impact on economic growth (3SLS)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| *Economic growth* | *g7000* | *g7000* | *g7000* | *g7000* | *g7000* | *g7000* | *g7000* | *g7000* |
| minxp | −4.625 | −2.885 | 2.431 | 3.417 | 3.666 | 3.144 | −1.464 | −2.992 |
| | (3.13) | (3.55) | (2.96) | (3.18) | (2.67) | (2.75) | (3.73) | (3.23) |
| mineral abund. | 0.345*** | 0.198 | 0.134** | 0.094 | 0.055 | 0.057 | 0.261*** | 0.308*** |
| | (0.13) | (0.15) | (0.060) | (0.058) | (0.074) | (0.077) | (0.091) | (0.084) |
| rule | 1.666* | | 2.658*** | | 2.274** | | 1.280 | |
| | (0.92) | | (0.98) | | (1.05) | | (1.17) | |
| goveffect | | 2.371 | | 3.089** | | 2.473** | | 1.440 |
| | | (1.62) | | (1.22) | | (1.17) | | (1.08) |
| lgdp70 | −2.073*** | −1.953 | −1.843** | −1.879** | −1.604* | −1.737* | −1.097 | −1.395 |
| | (0.80) | (1.25) | (0.79) | (0.92) | (0.87) | (0.97) | (0.96) | (0.90) |
| $R^2$ | 0.58 | 0.44 | 0.37 | 0.24 | 0.33 | 0.30 | 0.49 | 0.53 |
| *Min. dependence* | *minxp* | *minxp* | *minxp* | *minxp* | *minxp* | *minxp* | *minxp* | *minxp* |
| pres70s | 0.035 | 0.038* | 0.036 | 0.036 | 0.059*** | 0.051** | 0.052** | 0.041* |
| | (0.022) | (0.021) | (0.024) | (0.022) | (0.023) | (0.022) | (0.025) | (0.023) |
| mineral abund. | 0.016*** | 0.015*** | 0.010*** | 0.010*** | 0.016*** | 0.016*** | 0.017*** | 0.016*** |
| | (0.005) | (0.005) | (0.002) | (0.002) | (0.003) | (0.003) | (0.003) | (0.003) |
| rule | −0.027 | | 0.005 | | −0.018 | | −0.027 | |
| | (0.017) | | (0.017) | | (0.017) | | (0.017) | |
| goveffect | | −0.018 | | 0.013 | | −0.008 | | −0.017 |
| | | (0.017) | | (0.017) | | (0.016) | | (0.016) |
| open5060s | 0.259*** | 0.261*** | 0.194*** | 0.197*** | 0.191*** | 0.201*** | 0.199*** | 0.240*** |
| | (0.040) | (0.038) | (0.025) | (0.024) | (0.023) | (0.023) | (0.037) | (0.037) |
| $R^2$ | 0.60 | 0.62 | 0.52 | 0.49 | 0.58 | 0.59 | 0.57 | 0.63 |
| *Institutions* | *rule* | *goveffect* | *rule* | *goveffect* | *rule* | *goveffect* | *rule* | *goveffect* |
| latitude | 2.920*** | 2.284*** | 2.159*** | 1.981*** | 2.071*** | 1.921*** | 2.898*** | 2.841*** |
| | (0.59) | (0.59) | (0.57) | (0.56) | (0.59) | (0.60) | (0.62) | (0.62) |
| mineral abund. | 0.104*** | 0.110*** | −0.006 | 0.005 | 0.024 | 0.031 | 0.004 | 0.003 |
| | (0.039) | (0.040) | (0.016) | (0.015) | (0.024) | (0.025) | (0.028) | (0.028) |
| $R^2$ | 0.77 | 0.76 | 0.65 | 0.67 | 0.64 | 0.64 | 0.65 | 0.67 |
| Mineral abund. var. | lsubsoil | lsubsoil | lhcpc | lhcpc | lallminpc | lallminpc | lsubsoil00 | lsubsoil00 |
| Obs | 58 | 58 | 86 | 86 | 84 | 83 | 69 | 68 |
| Wald test min. ab. | 22.24*** | 20.1*** | 43.31*** | 42.32*** | 44.73*** | 44.46*** | 43.12*** | 41.56*** |

*Notes*: All regressions are 3SLS. Regional dummy variables and constant term included in all specifications. The Wald test statistics refer to the hypothesis that the sum of the effects of the mineral abundance variable is insignificantly different from zero. Standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

and the magnitude and significance of the main coefficients of interest are generally consistent with our previous findings. We do not find that resource dependence significantly impacts the average growth rate, although the sign remains negative. Moreover, mineral resource abundance seems to have a positive overall effect on economic performance which is significantly different from zero ($p$-values for the Wald test of 0.0001 or below in all specifications), confirming our view that there is no real evidence of a curse. Again, when we limit our sample to democracies only we find substantially unchanged effects (see the Appendix for details).

## 3.4 Robustness with respect to alternative resource abundance measures

As mentioned above, it is challenging to find truly exogenous measures of resource abundance, and one might argue our abundance measure is not fully exogenous. To address this concern, we evaluate our model based on three alternative measures of resource abundance: (i) per capita hydrocarbon reserves in 1993 (in logs) from Sala-i-Martin et al. (2004) (*lhcpc*), which exclude all non-fuel mineral resources; (ii) estimates of the per capita value of 1970 stocks (in logs) of the main fuel and non-fuel mineral resources, provided by Norman (2006) (*lallminpc*); and (iii) the (log of) World Bank resource abundance measures for 2000 (*lsubsoil00*) (World Bank, 2005).

For all these alternative measures, we find that the "resource curse" result disappears when we instrument for dependence, and that abundance is positively linked to dependence. For space reasons, we only present 3SLS results; further results are available in the Appendix. Columns (3)-(4) of Table 3.5 show the findings using the hydrocarbon data as the abundance variable; in columns (5)-(6) we employ the mineral stocks estimates; and in columns (7)-(8) we use the subsoil wealth measures for 2000. With all alternative measures, the direct effect of mineral abundance on growth in the third stage continues to be positive and even significant (in the case of hydrocarbons and the 2000 subsoil wealth data). As expected, we also find that resource abundance positively affects dependence. Moreover, there is no evidence that resource dependence, when instrumented for, lowers growth rates: on the contrary, dependence even enters with a positive sign in several cases. However, we find no significant effect of mineral abundance on institutional quality with any alternative measure, although the sign is positive in all cases but one (see the bottom panel).

## 3.5 Conclusions and discussion

The paradoxical finding of a negative relationship between a sizable resource sector and economic growth has attracted widespread attention from academics, policy makers and international organizations. The main causal mechanism linking resources to poor performance is commonly hypothesized to be "executive discretion over resource rents" (Jensen and Wantchekon, 2004). According to this view, an abundance of rents allows incumbent politicians to maintain support and consolidate their power base through repression, buying off the opposition, or institutionalized patronage (including massive spending on public service employment). Since such policies are unlikely to promote economic growth, it is no surprise that economic and political performance is not independent. The logic of the story, combined with the fact that it is corroborated with observations of certain countries in the developing world, has undoubtedly added to the appeal of the resource curse hypothesis.

However, our empirical results cast new light on the validity of this emerging consensus. In discussing the impact of natural resources on growth, it is useful to distinguish between resource abundance (a stock measure of in situ resource wealth), resource rents (the flow of income derived from the resource stock at some point in time), and resource dependence (the degree to which countries do – or do not – have access to alternative sources of income other than resource extraction, again at some point in time). Although possibly correlated, these concepts are not equivalent. In fact, there exists a discrepancy between the theory behind the curse, and the empirical work used to support it. While abundant resource rents are a crucial element in the theory, most previous analyses rely on a measure of resource dependence, and our analysis suggests that resource dependence may not be a proper exogenous variable. Treating resource dependence as endogenous, we find it to be insignificant in growth regressions, with no effect on institutional quality. While we find resource abundance to be significantly associated with both growth and institutional quality, the association runs contrary to the resource curse hypothesis: greater abundance leads to better institutions and more rapid growth. In short, the received result that resource wealth impedes growth appears to be a red herring, and suggestions that countries should turn their back on resource wealth to lower resource dependence may have to be reconsidered.

How may we reconcile our finding that resource-abundant countries could in fact be better off than resource-poor ones with the existing literature? One possible explanation may be that resources in the ground do not pose the same problem for institutional quality or economic performance as flows of resource rents do. But this begs another question – since resource stocks can be converted into flows of money, why would outcomes for stocks and flows be different? Another possible explanation would be more straightforward and fully consistent with our main findings, namely that the curse simply does not exist. The empirically significant relationship between institutional quality and resource dependence reflects that countries with poor institutions are unlikely to develop non-primary production sectors to reduce their dependence on resource exports. If so, the causality would be from institutions to dependence, and not the other way around. It would be inappropriate to talk about the "curse of resources" then. Instead, growth regressions in the resource curse literature may be viewed as a reminder of the important direct and indirect impacts of institutions on economic outcomes.

## 3.6 Appendix

Table 3.6: Correlations between different proxies for natural resource abundance

| | sxp | natxp70 | minxp70 | natxp | minxp | lnatcap | lsubsoil | lhcpc | mintpc70 |
|---|---|---|---|---|---|---|---|---|---|
| natxp70 | 0.705* | | | | | | | | |
| | (0.577*) | | | | | | | | |
| | [74] | | | | | | | | |
| minxp70 | 0.791* | 0.884* | | | | | | | |
| | (0.538*) | (0.625*) | | | | | | | |
| | [81] | [69] | | | | | | | |
| natxp | 0.657* | 0.814* | 0.897* | | | | | | |
| | (0.521*) | (0.609*) | (0.668*) | | | | | | |
| | [106] | [76] | [86] | | | | | | |
| minxp | 0.672* | 0.782* | 0.9263* | 0.984* | | | | | |
| | (0.447*) | (0.489*) | (0.845*) | (0.886*) | | | | | |
| | [106] | [76] | [86] | [123] | | | | | |
| lnatcap | 0.118 | 0.147 | 0.146 | 0.359* | 0.332* | | | | |
| | (−0.03) | (−0.084) | (−0.134) | (0.286*) | (0.245*) | | | | |
| | [84] | [62] | [69] | [83] | [83] | | | | |
| lsubsoil | 0.279* | 0.361* | 0.309* | 0.505* | 0.509* | 0.707* | | | |
| | (0.173) | (0.308*) | (0.293*) | (0.448*) | (0.534*) | (0.654*) | | | |
| | [61] | [47] | [51] | [61] | [61] | [63] | | | |
| lhcpc | 0.215* | 0.088 | 0.143 | 0.327* | 0.363* | 0.4064* | 0.592* | | |
| | (0.091) | (0.168) | (0.316*) | (0.423*) | (0.495*) | (0.387*) | (0.694*) | | |
| | [100] | [71] | [79] | [101] | [101] | [89] | [63] | | |
| mintpc70 | 0.544* | 0.529* | 0.608* | 0.607* | 0.640* | 0.517* | 0.637* | 0.295* | |
| | (0.181) | (0.168) | (0.521*) | (0.462*) | (0.575*) | (0.343*) | (0.518*) | (0.498*) | |
| | [98] | [72] | [75] | [99] | [99] | [77] | [60] | [97] | |
| lallminpc | 0.382* | 0.303* | 0.438* | 0.483* | 0.539* | 0.457* | 0.799* | 0.623* | 0.394* |
| | (0.258*) | (0.199) | (0.539*) | (0.528*) | (0.661*) | (0.437*) | (0.806*) | 0.626*) | (0.771*) |
| | [103] | [75] | [81] | [107] | [107] | [83] | [62] | [104] | [114] |

*Notes*: The table depicts Pearson's correlations and Spearman's rank correlations in parentheses below, with the number of observations in square brackets. * denotes significance at 5 percent level or below. *sxp* is the GNP share of total primary exports from Sachs & Warner (1997); *natxp*70 is the GDP share of total primary resource exports in 1970; and *minxp*70 is the corresponding GDP share of mineral exports only. *lhcpc* is the log of hydrocarbon deposits in 1993, from Sala-i-Martin et al. (2004); *mintpc*70 is the 1970 per capita mineral output in tons, from IGS (1978) and the BP database; *lallminpc* measures (log) total fuel and nonfuel mineral reserves in 1970 in current prices (in USD per capita), from Norman (2006).

Table 3.7: Institutions, constitutions, and natural resources

| | (1) rule | (2) goveffect | (3) rule | (4) goveffect | (5) rule | (6) goveffect | (7) rule | (8) goveffect |
|---|---|---|---|---|---|---|---|---|
| latitude | 2.480*** | 2.130*** | 3.041*** | 2.383*** | 2.519*** | 2.367*** | 3.310*** | 2.982*** |
| | (0.579) | (0.629) | (0.658) | (0.749) | (0.74) | (0.806) | (0.883) | (0.986) |
| pres70s | −0.338** | −0.26 | −0.24 | −0.134 | −0.366* | −0.118 | −0.19 | 0.09 |
| | (0.164) | (0.167) | (0.176) | (0.169) | (0.191) | (0.211) | (0.245) | (0.241) |
| maj70s | 0.246* | 0.132 | 0.024 | −0.02 | 0.262* | 0.198 | 0.126 | 0.054 |
| | (0.129) | (0.131) | (0.13) | (0.133) | (0.142) | (0.151) | (0.135) | (0.158) |
| lnatcap | 0.254** | 0.290*** | | | 0.286** | 0.281** | | |
| | (0.097) | (0.105) | | | (0.107) | (0.116) | | |
| lsubsoil | | | 0.133*** | 0.149*** | | | 0.152** | 0.167** |
| | | | (0.049) | (0.053) | | | (0.061) | (0.065) |
| Sample | All | All | All | All | Dems | Dems | Dems | Dems |
| Obs | 68 | 68 | 54 | 54 | 53 | 53 | 42 | 42 |
| F-stat | 47.54*** | 36.76*** | 44.85*** | 31.52*** | 41.28*** | 30.88*** | 37.82*** | 26.73*** |
| $R^2$ | 0.78 | 0.78 | 0.82 | 0.79 | 0.79 | 0.77 | 0.83 | 0.8 |

*Notes*: All regressions are OLS. Regional dummy variables and constant term included in all specifications. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 3.8: Mineral dependence and institutions (democracies)

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | minxp | minxp | rule | goveffect | minxp | minxp |
| pres70s | 0.055 | 0.061* | | | 0.052 | 0.061* |
| | (0.036) | (0.033) | | | (0.038) | (0.035) |
| maj70s | 0.024 | 0.022 | | | 0.024 | 0.022 |
| | (0.025) | (0.025) | | | (0.025) | (0.025) |
| lsubsoil | 0.015*** | 0.017*** | 0.165*** | 0.162*** | 0.016** | 0.017*** |
| | −0.005 | −0.005 | (0.051) | (0.051) | (0.006) | (0.006) |
| rule | −0.029** | | | | −0.036 | |
| | (0.015) | | | | (0.024) | |
| goveffect | | −0.045*** | | | | −0.041* |
| | | (0.015) | | | | (0.025) |
| open5060s | 0.292*** | 0.297*** | | | 0.295*** | 0.295*** |
| | (0.071) | (0.066) | | | (0.071) | (0.066) |
| latitude | | | 3.566*** | 2.889*** | | |
| | | | (0.75) | (0.80) | | |
| Obs | 40 | 40 | 42 | 42 | 40 | 40 |
| Estimation meth. | OLS | OLS | OLS | OLS | 2SLS | 2SLS |
| F-stat | 2.72** | 3.24*** | 43.66*** | 37.08*** | | |
| $R^2$ | 0.62 | 0.66 | 0.82 | 0.80 | | |

*Notes*: Regional dummy variables and constant term included in all specifications. Country sample includes democracies only, defined by a 1972 Gastil score between 0 and 5. Columns (5)-(6) show 2SLS results (second stage only), where institutions are instrumented by *latitude*. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 3.9: Mineral dependence and the finer points of constitutional design

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | minxp | minxp | minxp | minxp |
| majpres | 0.074** | 0.074** | 0.090** | 0.096*** |
| | (0.035) | (0.036) | (0.040) | (0.036) |
| propres | 0.054* | 0.054* | 0.108* | 0.121** |
| | (0.029) | (0.031) | (0.055) | (0.051) |
| majpar | 0.027 | 0.023 | 0.060** | 0.064** |
| | (0.027) | (0.029) | (0.027) | (0.026) |
| lnsubsoil | 0.021*** | 0.022*** | 0.016*** | 0.018*** |
| | (0.006) | (0.006) | (0.005) | (0.005) |
| open5060s | 0.260*** | 0.257*** | 0.299*** | 0.305*** |
| | (0.070) | (0.068) | (0.071) | (0.066) |
| rule | −0.035** | | −0.029* | |
| | (0.014) | | (0.015) | |
| goveffect | | −0.038** | | −0.047*** |
| | | (0.016) | | (0.015) |
| Sample | all | all | dems | dems |
| Obs | 52 | 52 | 40 | 40 |
| F-stat | 3.12*** | 3.23*** | 2.70** | 3.26*** |
| Wald test $p$-value | 0.15 | 0.16 | 0.11 | 0.05 |
| $R^2$ | 0.58 | 0.58 | 0.63 | 0.67 |

*Notes*: All regressions are OLS with regional control variables and constant term. *majpres* is dummy variable for majoritarian electoral rules and presidential governmental system; *propres* for proportional electoral rules and presidential system; *majpar* for majoritarian electoral rules and parliamentary system; and *propar* is the omitted dummy variable, referring to proportional electoral rules in a parliamentary system. Europe and Central Asia is omitted regional dummy variable. $p$-values are given for the Wald test of joint significance of the constitutional dummy variables (null hypothesis of joint significance insignificantly different from zero). Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 3.10: Mineral dependence and alternative resource measures (full sample)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| pres70s | 0.055*** | 0.028 | 0.032 | 0.065*** | 0.053** | 0.045* | 0.073*** | 0.059** | 0.048** |
| | (0.017) | (0.022) | (0.023) | (0.017) | (0.025) | (0.026) | (0.020) | (0.024) | (0.024) |
| maj70s | 0.018 | 0.016 | 0.013 | 0.028* | 0.02 | 0.024 | 0.026 | 0.006 | 0.014 |
| | (0.016) | (0.021) | (0.021) | (0.016) | (0.021) | (0.022) | (0.018) | (0.021) | (0.022) |
| min. abund. | 0.008*** | 0.009*** | 0.009*** | 0.015*** | 0.016*** | 0.016*** | 0.015*** | 0.019*** | 0.018*** |
| | (0.002) | (0.002) | (0.002) | (0.003) | (0.003) | (0.003) | (0.003) | (0.004) | (0.003) |
| rule | | −0.022* | | | -0.0187* | | | -0.0144 | |
| | | (0.011) | | | (0.0098) | | | (0.011) | |
| goveffect | | | −0.017 | | | −0.020* | | | −0.019 |
| | | | (0.015) | | | (0.011) | | | (0.012) |
| open5060s | 0.174*** | 0.179*** | 0.177*** | 0.165*** | 0.171*** | 0.179*** | 0.191*** | 0.178*** | 0.206*** |
| | (0.032) | (0.028) | (0.031) | (0.025) | (0.023) | (0.024) | (0.060) | (0.056) | (0.054) |
| Min. abund. var. | lhcpc | lhcpc | lhcpc | lallminpc | lallminpc | lallminpc | lsubsoil00 | lsubsoil00 | lsubsoil00 |
| Obs | 70 | 70 | 70 | 73 | 73 | 72 | 60 | 60 | 59 |
| Regional controls | no | yes | yes | no | yes | yes | no | yes | yes |
| F-stat | 9.06*** | 5.60*** | 7.92*** | 12.98*** | 7.34*** | 8.19*** | 8.99*** | 4.17*** | 4.52*** |
| $R^2$ | 0.41 | 0.44 | 0.44 | 0.52 | 0.54 | 0.56 | 0.47 | 0.52 | 0.57 |

*Notes*: All regressions are OLS. Dependent variable is mineral dependence (*minxp*). Constant term included in all specifications. Robust standard errors in parentheses.
*, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 3.11: Mineral dependence and alternative resource measures (democracies)

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| pres70s | 0.022 | 0.022 | 0.055 | 0.041 | 0.068* | 0.045 |
| | (0.036) | (0.033) | (0.037) | (0.038) | (0.037) | (0.035) |
| maj70s | 0.022 | 0.019 | 0.0241 | 0.0301 | 0.0166 | 0.0251 |
| | (0.023) | (0.022) | (0.024) | (0.026) | (0.025) | (0.026) |
| min. abund. | 0.010*** | 0.011*** | 0.015*** | 0.015*** | 0.019*** | 0.019*** |
| | (0.002) | (0.003) | (0.003) | (0.003) | (0.004) | (0.004) |
| rule | −0.020* | | −0.016 | | −0.013 | |
| | (0.011) | | (0.011) | | (0.013) | |
| goveffect | | −0.028** | | −0.028** | | −0.030** |
| | | (0.013) | | (0.012) | | (0.013) |
| open5060s | 0.189*** | 0.195*** | 0.172*** | 0.187*** | 0.186*** | 0.216*** |
| | (0.030) | (0.031) | (0.025) | (0.025) | (0.055) | (0.052) |
| Min. abund. var. | lhcpc | lhcpc | lallminpc | lallminpc | lsubsoil00 | lsubsoil00 |
| Obs | 54 | 54 | 57 | 56 | 47 | 46 |
| F-stat | 5.81*** | 7.20*** | 6.89*** | 8.49*** | 3.22*** | 3.86*** |
| $R^2$ | 0.53 | 0.54 | 0.56 | 0.60 | 0.53 | 0.61 |

*Notes*: All regressions are OLS. Dependent variable is mineral dependence (*minxp*). Regional controls and constant term included in all specifications. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 3.12: Mineral dependence, institutional design and growth impacts with alternative resource measures (full sample)

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| minxp | 1.896 | 2.396 | 2.992 | 2.567 | -2.133 | -3.453 |
| | (2.52) | (2.11) | (2.71) | (2.44) | (4.36) | (3.84) |
| min.abund. | 0.120*** | 0.097** | 0.08 | 0.086 | 0.288*** | 0.320*** |
| | (0.046) | (0.044) | (0.055) | (0.053) | (0.11) | (0.094) |
| rule | 1.470*** | | 1.215*** | | 0.996*** | |
| | (0.31) | | (0.31) | | (0.30) | |
| goveffect | | 1.399*** | | 1.180*** | | 1.076*** |
| | | (0.31) | | (0.28) | | (0.34) |
| lgdp70 | −1.353*** | −1.249*** | −1.230*** | −1.239*** | −1.193*** | −1.304*** |
| | (0.36) | (0.34) | (0.35) | (0.32) | (0.37) | (0.38) |
| Min.abund.var. | lhcpc | lhcpc | lallminpc | lallminpc | lsubsoil00 | lsubsoil00 |
| Obs | 86 | 86 | 84 | 83 | 69 | 68 |
| F-stat | 7.23*** | 11.68*** | 6.88*** | 10.52*** | 5.08*** | 7.77*** |
| Excl. F-stat | 20.68*** | 28.68*** | 27.05*** | 38.85*** | 5.79*** | 8.92*** |
| Hansen J p-value | 0.97 | 0.81 | 0.49 | 0.36 | 0.35 | 0.26 |
| Shea partial $R^2$ | 0.46 | 0.49 | 0.47 | 0.52 | 0.3 | 0.38 |
| 1st stage $R^2$ | 0.57 | 0.61 | 0.59 | 0.64 | 0.58 | 0.66 |

*Notes*: All regressions are 2SLS, with (log) income growth 1970-2000 as the dependent variable in the second stage and mineral dependence in the first stage. Regional controls and constant term included in all specifications. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 3.13: Mineral dependence, institutional design and growth impacts (democracies)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| minxp | −3.956 | −2.934 | 0.254 | 0.240 | 1.102 | −0.113 | −4.583 | −6.422 |
| | (3.61) | (3.59) | (2.98) | (2.554) | (3.44) | (2.94) | (5.47) | (4.92) |
| min.abund. | 0.198* | 0.177* | 0.095* | 0.071 | 0.019 | 0.049 | 0.234* | 0.251** |
| | (0.12) | (0.10) | (0.051) | (0.044) | (0.060) | (0.056) | (0.12) | (0.10) |
| rule | 1.517*** | | 2.053*** | | 1.603*** | | 1.354*** | |
| | (0.55) | | (0.54) | | (0.50) | | (0.44) | |
| goveffect | | 1.144** | | 1.853*** | | 1.681*** | | 1.573*** |
| | (0.53) | | 0.4573496 | | (0.44) | | (0.41) | |
| lgdp70 | −1.812*** | −1.402** | −1.934*** | −1.732*** | −1.532*** | −1.713*** | −1.545*** | −1.803*** |
| | (0.56) | (0.57) | (0.53) | (0.468) | (0.55) | (0.48) | (0.57) | (0.46) |
| Min.abund.var. | lsubsoil | lsubsoil | lhcpc | lhcpc | lallminpc | lallminpc | lsubsoil00 | lsubsoil00 |
| Obs | 40 | 40 | 56 | 56 | 56 | 55 | 45 | 44 |
| F-stat | 3.05** | 5.22*** | 5.45*** | 7.04*** | 6.32*** | 7.63*** | 2.61** | 2.99*** |
| Excl. F-stat | 6.08*** | 10*** | 10.89*** | 11.07*** | 15.23*** | 17.51*** | 2.96* | 5.34*** |
| Hansen J p-value | 0.79 | 0.76 | 0.16 | 0.04 | 0.30 | 0.20 | 0.44 | 0.45 |
| Shea partial $R^2$ | 0.48 | 0.56 | 0.45 | 0.5 | 0.47 | 0.54 | 0.28 | 0.40 |
| 1st stage $R^2$ | 0.62 | 0.7 | 0.52 | 0.55 | 0.56 | 0.61 | 0.52 | 0.61 |

*Notes*: All regressions are 2SLS, with (log) income growth 1970-2000 as the dependent variable in the second stage and mineral dependence in the first stage. Regional controls and constant term included in all specifications. Robust standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 3.14: 3SLS for democracies only

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| *Economic growth* | *g7000* | *g7000* | *g7000* | *g7000* | *g7000* | *g7000* | *g7000* | *g7000* |
| minxp | −3.878 | −2.601 | 0.309 | 0.118 | 0.747 | 0.738 | $-7.350^{*}$ | $-9.149^{*}$ |
| | (3.61) | (3.76) | (7.31) | (4.16) | (3.53) | (5.59) | (4.39) | (4.97) |
| min.abund. | $0.286^{**}$ | $0.288^{*}$ | 0.059 | 0.082 | 0.043 | 0.061 | $0.326^{**}$ | $0.367^{***}$ |
| | (0.14) | (0.15) | (0.097) | (0.068) | (0.073) | (0.10) | (0.13) | (0.14) |
| rule | 0.544 | | | 1.267 | 0.734 | | 0.629 | |
| | (1.29) | | | (1.31) | (1.20) | | (1.42) | |
| goveffect | | −0.121 | −0.039 | | | 0.174 | | 0.716 |
| | | (1.72) | (2.42) | | | (1.99) | | (2.20) |
| lgdp70 | −1.343 | −0.802 | −0.813 | −1.491 | −1.131 | −0.869 | −1.547 | −1.907 |
| | (1.14) | (1.38) | (2.17) | (1.21) | (1.07) | (1.84) | (1.25) | (1.93) |
| $R^2$ | 0.50 | 0.43 | 0.19 | 0.47 | 0.43 | 0.34 | 0.39 | 0.33 |
| *Min. dependence* | *minxp* | *minxp* | *minxp* | *minxp* | *minxp* | *minxp* | *minxp* | *minxp* |
| pres70s | 0.051 | $0.063^{**}$ | 0.001 | 0.001 | $0.051^{*}$ | 0.045 | 0.049 | 0.045 |
| | (0.034) | (0.031) | (0.026) | (0.030) | (0.029) | (0.029) | (0.035) | (0.032) |
| min.abund. | $0.013^{*}$ | $0.011^{*}$ | $0.011^{***}$ | $0.011^{***}$ | $0.016^{***}$ | $0.015^{***}$ | $0.019^{***}$ | $0.018^{***}$ |
| | (0.007) | (0.007) | (0.002) | (0.004) | (0.003) | (0.003) | (0.005) | (0.004) |
| rule | −0.019 | | | −0.017 | $-0.034^{*}$ | | $-0.036^{*}$ | |
| | (0.020) | | | (0.018) | (0.018) | | (0.020) | |
| goveffect | | −0.004 | −0.01 | | | −0.022 | | −0.020 |
| | | (0.020) | (0.017) | | | (0.017) | | (0.018) |
| open5060s | $0.292^{***}$ | $0.298^{***}$ | $0.196^{***}$ | $0.192^{***}$ | $0.190^{***}$ | $0.204^{***}$ | $0.190^{***}$ | $0.247^{***}$ |
| | (0.050) | (0.048) | (0.028) | (0.029) | (0.027) | (0.027) | (0.047) | (0.047) |
| $R^2$ | 0.61 | 0.60 | 0.51 | 0.51 | 0.55 | 0.60 | 0.49 | 0.59 |
| *Institutions* | *rule* | *goveffect* | *rule* | *goveffect* | *rule* | *goveffect* | *rule* | *goveffect* |
| latitude | $3.501^{***}$ | $2.630^{***}$ | $2.392^{***}$ | $3.024^{***}$ | $2.713^{***}$ | $2.152^{***}$ | $3.754^{***}$ | $3.195^{***}$ |
| | (0.67) | (0.72) | (0.80) | (0.77) | (0.75) | (0.80) | (0.76) | (0.78) |
| min.abund. | $0.160^{***}$ | $0.160^{***}$ | −0.001 | −0.012 | 0.031 | 0.033 | 0.039 | 0.055 |
| | (0.043) | (0.047) | (0.022) | (0.021) | (0.028) | (0.030) | (0.036) | (0.038) |
| Min. abund. var. | lsubsoil | lsubsoil | lhcpc | lhcpc | lallminpc | lallminpc | lsubsoil00 | lsubsoil00 |
| Obs | 40 | 40 | 56 | 56 | 56 | 55 | 45 | 44 |
| $R^2$ | 0.83 | 0.80 | 0.65 | 0.67 | 0.70 | 0.67 | 0.73 | 0.72 |
| Wald test min.abund. | 20.12 | 18.98 | 25.12 | 24.95 | 28.23 | 27.88 | 23.09 | 26.09 |

*Notes*: All regressions are 3SLS. The Wald test statistics refer to the hypothesis that the sum of the effects of the mineral abundance variable is insignificantly different from zero. Standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively.

Table 3.15: Variables and sources

ECONOMIC DEVELOPMENT

**g7000**: Log of growth of real GDP per capita between 1970-2000. Source: PWT 6.1.

**lgdp70**: Log of real GDP per capita in 1970. Source: PWT 6.1.

RESOURCE EXPORTS AND ABUNDANCE

**agrixp**: GDP share of yearly agricultural raw materials exports, averaged over 1970-2000. Agricultural raw materials comprise SITC section 2 (crude materials except fuels) excluding divisions 22, 27 (crude fertilizers and minerals excluding coal, petroleum, and precious stones), and 28 (metalliferous ores and scrap). Sources: WDI, PWT 6.1.

**lallminpc**: Log of fuel and 35 non-fuel mineral stocks estimated for 1970 at market prices, in USD per capita. Sources: Norman (2007) and PWT 6.1 (for population data).

**lhcpc**: Log of per capita hydrocarbon deposits in 1993. Source: Sala-i-Martin et al. (2004).

**lnatcap**: Log of total natural capital, estimated in USD per capita for 1994. The measure includes subsoil assets, timber resources, non-timber forest resources, protected areas, cropland, and pastureland. Source: World Bank (1997).

**lsubsoil, lsubsoil00**: Log of subsoil assets, estimated in USD per capita for 1994 and 2000, respectively. The measure includes energy resources (oil, natural gas, hard coal, lignite) and other mineral resources (bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin, zinc). Sources: World Bank (1997, 2005).

**minxp**: GDP share of total yearly mineral exports, defined as the sum of mineral fuels, ores and metal exports, averaged over 1970-2000. Fuels comprise SITC section 3 (mineral fuels); ores and metals comprise the commodities in SITC sections 27 (crude fertilizer, minerals not elsewhere specified (n.e.s.)), 28 (metalliferous ores, scrap), and 68 (non-ferrous metals). Sources: WDI, PWT 6.1.

**natxp**: GDP share of total yearly natural resource exports, defined as the sum of mineral and agricultural raw materials exports, averaged over 1970-2000. Sources: WDI, PWT 6.1.

CONSTITUTIONS AND INSTITUTIONS

**goveffect**: Measures the quality of the bureaucracy and of public services in 1996. Recalibrated to assume values between zero (worst) and 5 (best). Source: Kaufmann et al. (2005).

**maj70s**: Binary indicator for majoritarian (plurality) elections of house representatives. Coded 1 when majority or all house members elected by plurality rule. Coded 0 when majority or all members elected by proportional rule. Value for early 1970s. Sources: Beck et al. (2005), Persson & Tabellini (2004).

**pres70s**: Binary indicator for form of government, coded 1 if the chief executive is directly presidential or a strong president elected by an assembly. Coded 0 if parliamentary. Value for early 1970s. Sources: Beck et al. (2005), Persson & Tabellini (2004).

**rule**: Measures the quality of contract enforcement, the police and the courts, as well as the likelihood of crime and violence in 1996. Recalibrated to assume values between zero (worst) and 5 (best). Source: Kaufmann et al. (2005).

OTHER VARIABLES

**latitude**: Absolute value of latitude of a country on a scale of 0 to 1. Source: La Porta et al. (1999).

**open5060s**: Measure of trade openness (in nominal terms), defined as the sum of imports and exports over GDP. Average between 1950 and 1969. Source: PWT 6.1.

# Chapter 4

# Financing the alternative: renewable energy in developing and transition countries

This paper examines the determinants of credit allocation to renewable energy firms in developing and transition countries. Using a simple endogenous growth model, we show that the development of the renewable energy sector, i.e. the diversification of renewable energy resources used in primary energy production, depends on the quality of financial intermediation, debtor information costs to banks, and financing needs of renewable energy firms. Policies should aim at increasing financial sector performance through better institutional frameworks and improving financing conditions for new energy firms. The empirical analysis confirms the positive effect of financial intermediary development on the renewable energy sector.

## 4.1 Introduction

Achieving a diversified and sustainable energy supply for future generations is one of the major challenges for today's policymakers. But financing the necessary energy projects is proving a serious obstacle to this goal. Over the next twenty-five years, global energy demand is projected to grow by nearly 60 percent; more than two thirds of the increased demand will come from developing and transition countries. Energy demand will continue to be covered mainly by conventional fossil fuels, such as coal, oil, and natural gas, with over two thirds of the energy-related pollution increase coming from the developing world (IEA, 2005). Meanwhile, many estimates predict that oil and possibly natural gas production will plateau around the same time, casting doubt on future energy security.[1] Hence, achieving a sustainable energy supply requires diversifying energy sources and changing the current dependence on non-renewable and polluting hydrocarbon fuels.

However, energy projects generally demand high levels of financing, which producers in less developed economies can rarely cover on their own; but obtaining sufficient investment to pursue energy diversification faces a number of obstacles (World Bank, 1999; IEA, 2003). More precisely, the financing for renewable energy technologies (RETs) is closely connected to the development of the financial sector:[2] on the one hand, energy sector privatization and liberalization during the course of the 1990s have increased the contribution of smaller private power projects, and at the same time induced a shift in external financing from the local government and multilateral institutions to private investors (Babbar and Schuster, 1998). On the other hand, re-

[1] The U.S. Energy Information Administration (EIA, 2000) alone has published several different scenarios, with global oil production peaking between 2021 and 2112.

[2] Another important issue regards the institutional framework: as previous literature has pointed out, limited financing of RETs derives both from the lack of a specific policy design, and/or crowding-out effects from government policies favoring investment in fossil fuel projects (Churchill and Saunders, 1989; Head, 2000; World Bank, 2002; Sonntag-O'Brien and Usher, 2004b; UNEP FI, 2004). Institutional shortcomings also contribute to the often limited consideration by potential investors of the positive environmental externalities of RETs in project development costs. In general, the perception that energy sustainability is not a top priority for policymakers further lowers investors' willingness to finance projects where the foreseeable rewards are already relatively low and long in the coming.

newable energy (RE) projects have very high start-up costs relative to the expected monetary returns, and very lengthy payback periods; they therefore typically require long-term maturity loans (UNEP FI, 2004; Sonntag-O'Brien and Usher, 2004b).

Accordingly, the problem of financing RE projects is twofold: first, the availability of the long-term loans needed by RET firms is positively linked to the development of the banking system (Demirgüç-Kunt and Maksimovic, 1999). As a consequence, RE projects in less developed countries are at a particular disadvantage.[3] Second, RET firms firms have limited access to financing because RE projects compete against fossil fuel projects, which have a longer track record, relatively lower up-front costs, shorter lead times, and often favorable political treatment (Churchill and Saunders, 1989; Head, 2000; World Bank, 2002; and Sonntag-O'Brien and Usher, 2004b).

It is worth noting that in both cases, underinvestment in RET firms can be interpreted in terms of imperfect information between firms and financiers: projects aimed at developing new technologies bear, almost by definition, greater information costs to investors, which are more easily borne by a highly developed financial sector. Where the latter is not given, the result may well be a market distortion in favor of less risky investments, such as fossil fuel projects and large-sized enterprises. This is consistent with the view that the development of the domestic financial sectors is the crucial factor in meeting the booming energy demand in less developed economies (Ishiguro and Akiyama, 1995; World Bank, 2003).[4]

Following this line of reasoning, the paper presents a multi-sector endogenous growth model of the expanding-varieties type (following Gries et

[3] In less developed economies, the banking sector is the major source of external financing (Tadesse, 2002; Carlin and Mayer, 2003; and Beck et al., 2004a), and access to bank credit is a serious problem especially for small- and medium-sized companies (Beck et al., 2004b).

[4] The notion that commercial financing plays an important role in RET expansion in developing countries is empirically confirmed by a number of case studies, for example on the experiences in Bangladesh and Sri Lanka.

al., 2004; and Romer, 1990), which is applied to explain the influence of financial intermediaries on the development of RETs in developing and transition countries. The focus is on the development of financial intermediaries – and especially the banking sector and banks' role as evaluators of potential debtors – as a driving force in the introduction of RETs in these countries. We assume imperfect information between RE entrepreneurs and financiers, and show that high information costs to determine creditworthy investment projects, and distortions in the banking sector, have a negative impact on the expansion of the RE sector. Greater RE development and economic growth in the model come from better financial intermediation and lower information costs to banks, as well as lower external financing needs for RE entrepreneurs. From this simple model, we can derive that policies should aim at improving financial sector performance in general and financing conditions for RE firms in particular, in order to foster the development of a diversified and sustainable energy sector.

The main theoretical findings on the determinants of renewable energy sector development are tested empirically in a series of panel data regressions for 118 non-OECD countries. The empirical results are fairly encouraging: they confirm the positive effect of financial sector and particularly banking sector development, as well as of power sector reforms, on the use of RETs in developing and transition countries – especially the newer technologies such as wind, solar, geothermal and biomass.

The paper is organized as follows. Section 4.2 contains the description of the model and the resulting steady-state equilibrium; policy implications are discussed in Section 4.3 and the empirical results given in Section 4.4; while section 4.5 concludes.

## 4.2 The model

The approach is based on a simple general equilibrium model of endogenous growth with three sectors: final and primary energy production, and the banking sector. The focus is on the development of the renewable energy (RE) sector in transition and developing economies. Experience in these countries shows that renewable energy technologies (RETs) have typically been adopted from developed countries and not been the result of domestic R&D. The model therefore considers only the expansion of renewable energy resources and firms using already-developed RETs and does not include an R&D sector.

**Final energy provision**

We assume that there are $N$ primary renewable energy producers in a given country, each supplying energy derived from a different RE resource $R_i$, e.g. hydropower, wind, geothermal, photovoltaic and solar thermal, biomass, etc., to the final energy producer. Final energy is produced by means of labour and primary RE resources $R_i$ according to the following extended Cobb-Douglas production function (Romer, 1990; Gries et al., 2004):

$$Y = L^{1-\alpha} \sum_{i=1}^{N} R_i^{\alpha}, \tag{4.1}$$

where $0 < \alpha < 1$. Since the production function is homogeneous of degree one, there will be constant returns to scale of all inputs taken together.[5] Following the basic idea of the expanding-varieties model, growth is driven by an expansion in $N$ (Barro and Sala-i-Martin, 2004), i.e. a diversification in the primary renewable energy sources. The latter is interpreted as beneficial for the sustainable development of the energy sector: a larger number of RE resources in primary energy production increases the share of RETs in

[5] The formulation used here also implies that the different types of primary renewable energy in a country are not perfect substitutes but have additively separate effects on a country's energy supply. In a particular case, a new type of primary renewable energy $i$ may substitute for an existing one $i'$, reducing its marginal productivity; but in finite time, the overall independence of marginal product will hold, following Barro and Sala-i-Martin (2004).

a country's energy supply, and by implication diminishes the dependence on existing primary energy resources used in energy production.

The final energy production sector behaves like a single competitive firm, which maximises profits according to

$$\pi_Y = Y - wL - \sum_{i=1}^{N} P_i R_i, \tag{4.2}$$

with $P_i$ denoting the price of primary resource $R_i$ and $w$ the wage rate. This implies a demand for primary RE resources given by

$$R_i = L\Big(\frac{\alpha}{P_i}\Big)^{\frac{1}{1-\alpha}}. \tag{4.3}$$

**Realization of primary RE production projects**

Primary RE production is relatively capital-intensive. Planning and implementing a new energy project, regardless of the type of resource used, is a very costly enterprise. And because of the additional costs facing RETs – e.g. long lead times, low levels of regulatory and financial support, and relatively high production costs in a fledgling industry where economies of scale and learning effects have only recently set in – renewable energy entrepreneurs in less developed economies are especially reliant on outside financing, as their own wealth is unlikely to be sufficient to cover their investment needs.[6]

In the model, the RE entrepreneur has own wealth of $W$, which by assumption is less than 1. He must therefore obtain $1-W = Z$ units of financing from an outside creditor in order to undertake a new energy project. If the creditor decides to award the loan necessary to finance the project, he will charge periodic interest payments $Zr_l$ on the credit.

The main source of finance for entrepreneurs in developing and transition countries is the banking sector. We exclude the possibility of Ponzi schemes

[6] Whether we consider a new investment project by an established firm or the start-up of a new energy firm, financing needs in the energy sector are still likely to surpass own wealth. For a study of the financing patterns of the energy sector in less developed countries, see World Bank (1999).

by assuming that firms revolve loans infinitely and service no more than the interest payments (Gries et al., 2004). With $r_d$ denoting the bank deposit rate, the present discounted value of the entrepreneur's setup costs is $V_s(t) = \int_t^\infty Z r_l e^{-\int_t^v r_d(s)ds}$. $r_d$ is constant in a steady-state equilibrium, and the setup costs simplify to

$$V_s = Z\frac{r_l}{r_d}. \tag{4.4}$$

After obtaining the initial project credit from the financier, profit flows of primary energy producers may continue to be affected by the quality of the banks' financial intermediation. The level of banking sector distortion is captured by $\tau$, which enters the profit stream as an indirect "tax" on banking services provided to the entrepreneur once he has been granted the initial loan. The "tax" rate $\tau$ depends on the legal and institutional environment and includes factors which influence banks' lending ability such as currency taxes, as well as accounting standards and the power of banks to draw up contracts.[7]

In addition, the RE producer will have to pay costs of $\delta$ on each unit of energy resource he uses. $\delta$ includes periodic costs of primary energy production, e.g. maintenance costs for wind mills or photovoltaic panels. The primary RE production sector cannot be described by a single firm; instead, there is a distinct firm $i$ which produces energy with each RE resource $R_i$. Once the primary energy producer has secured the financing of his project, he can supply his output to the final energy producer. In this form of monopolistic competition between primary RE producers, the present discounted value of the infinite stream of returns on the initial investment is given by $V_r(t) = \int_t^\infty \big((1-\tau)P_i - \delta\big) R_i e^{-\int_t^v r_d(s)ds}$. In the steady state, the interest rate

[7] King and Levine (1993b) introduced a similar financial sector "tax" caused by market distortions in their model. For empirical studies of indirect financial sector taxes, see Chamley and Honohan (1990) and Giovannini and de Melo (1993). For more on institutions and financial intermediation, see La Porta et al. (1997), Demirgüç-Kunt and Maksimovic (1998), Levine et al. (2000), and Beck et al. (2004a).

$r_d$ is constant and the net present value of returns is given by

$$V_r = \frac{1}{r_d} R_i \big( (1-\tau) P_i - \delta \big). \tag{4.5}$$

The primary energy producer takes the demand curve for primary RE by the final energy provider (4.3) as given when choosing the profit-maximizing price to set. Profit maximization gives the optimal primary resource price $P$, which holds for all RE resource types,

$$P = \frac{\delta}{\alpha} \frac{1}{(1-\tau)}. \tag{4.6}$$

Using the optimal price $P$ (4.6) and equation (4.3), and substituting them in (4.5) yields a net present value of the RE producer of

$$V_r = \frac{1}{r_d} L \left( \frac{1-\alpha}{\alpha} \right) \left( \frac{\alpha^2 (1-\tau)}{\delta^\alpha} \right)^{\frac{1}{1-\alpha}}. \tag{4.7}$$

Primary energy producers compete for bank credits to realize their projects; setup costs must therefore equal the net present value of profits $V_s = V_r$. This leads to a loan demand by the RE producers of

$$r_l = \frac{L}{Z} \left( \frac{1-\alpha}{\alpha} \right) \left( \frac{\alpha^2 (1-\tau)}{\delta^\alpha} \right)^{\frac{1}{1-\alpha}}. \tag{4.8}$$

Equation (4.8) gives the equilibrium interest on loan payments that the RE producers will be willing to pay the bank.

### The banking sector

Banks keep deposits $D$ and make interest payments to their depositors at rate $r_d$, and they allocate credits $Q$ at the loan rate $r_l$. Of potential RE entrepreneurs applying for a loan, only a fraction $\phi$ will actually be credit-worthy. However, there is a critical situation of imperfect information between the possible debtor and the investor: the financier cannot directly observe the quality of the investment project. Instead, he has to evaluate the RET project's potential at cost $f$ before deciding on credit allocation.

The reasoning is that although the entrepreneurs may observe their own potential costlessly, they cannot evaluate and credibly communicate it to the financial intermediators.[8] We assume that the financing constraints of RE entrepreneurs and information costs to financiers are similar across different RETs.

Banks are faced with a balance-sheet constraint which requires that total assets – credits $Q$ plus reserve holdings $RD$ – equal total liabilities, i.e. deposits $D$:

$$Q + RD = D. \tag{4.9}$$

In this model, we concentrate on the market distortions affecting the financial intermediation between banks and debtors, and assume that *interbank* frictions are negligible and reserve holdings unnecessary. This means that $RD = 0$ and that total credits $Q$ must equal total deposits $D$ at all times. Bank profits are thus given by

$$\pi_B = \left(r_l - \frac{f}{\phi}\right) Q - r_d Q. \tag{4.10}$$

Profit maximization yields the bank loan supply of

$$r_l = r_d + \frac{f}{\phi}. \tag{4.11}$$

The result corresponds to a situation with zero profits. Credit market equilibrium is given by $Q = ZN$.

### Households

The model uses a standard description of consumer preferences. The representative household maximizes intertemporal utility according to

$$U = \int_o^\infty \frac{C^{1-\sigma} - 1}{1-\sigma} e^{-\rho t} dt \qquad \text{for } \sigma \in [0, \infty). \tag{4.12}$$

[8] See King and Levine (1993b), and Fazzari et al. (1988) for more on the importance of imperfect information in new debt provision.

$\rho$ denotes the rate of time preference, and $1/\sigma$ indicates the intertemporal elasticity of substitution. The households' income will come from interest on deposits and wages and can be spent on consumption or savings (further deposits), giving the following budget constraint

$$Dr_d + wL = C + s = C + \dot{D}. \tag{4.13}$$

The first-order conditions imply the familiar Keynes-Ramsey rule:

$$\gamma_C = \frac{r_d - \rho}{\sigma}, \tag{4.14}$$

where $\gamma_C = \dot{C}/C$ is the equilibrium growth rate of consumption. In the steady state, consumption and output grow at the same rate $\gamma_C = \gamma_Y = \gamma$, and $r_d = \gamma\,\sigma + \rho$.

**Solution for the steady state**

Combining the primary RE producers' loan demand (4.8) with the banks' optimal loan supply (4.11) and the Keynes-Ramsey rule (4.14) gives us the solution to the model

$$\gamma = \frac{1}{\sigma}\left(\frac{L}{Z}\Big(\frac{1-\alpha}{\alpha}\Big)\Big(\frac{\alpha^2(1-\tau)}{\delta^\alpha}\Big)^{\frac{1}{1-\alpha}} - \rho - \frac{f}{\phi}\right). \tag{4.15}$$

This steady-state growth rate applies to the number of primary RE firms $N$, as well as output $Y$ and consumption $C$.

The most interesting aspects of the solution regard the signs of the terms involving the banking and RE sectors. Banking sector distortions, captured by $\tau$, will negatively affect growth, as less efficient financial intermediaries channel part of firms' profits away from growth-enhancing activities. Also, a higher proportion of creditworthy investment projects $\phi$ will have a positive effect not only on the RE sector's growth, but on the growth of the economy as a whole. We further see that higher information costs $f$ to the financier evaluating a potential creditor will result in lower growth rates.

A higher dependence of the RE producer on external financing for a project (a larger credit $Z$) is associated with a lower growth rate.[9] Similarly, higher resource costs to the primary RE producer $\delta$ will also result in less growth in the RE sector and the economy overall. Finally, the model shows that a greater willingness to save by the households – lower $\rho$ and $\sigma$ – raises the growth rate.

Possible extensions regard the inclusion of positive production externalities, e.g. better environmental quality and lower economic and social costs due to pollution. Through specific policies such as production subsidies and guaranteed feed-in prices, these benefits can be internalized to lower the production costs per unit of RE $\delta$. Formally, this can be represented as $\delta = \delta_0 - \epsilon$, where $\delta$ is the net total periodic production cost per unit of primary RE resource. $\delta_0$ includes the actual production cost such as equipment maintenance, while $\epsilon$ is the per-unit value of production externalities. It is easy to see that the inclusion of these externalities in the equation would have a positive impact on RE sector development.

## 4.3 Policy implications for RE sector development

The model's findings have several implications for the development of the renewable energy sector. We will discuss two main issues involving the banking sector, and other important points regarding RE production costs and the external financing needs.

First, the cost $\tau$ is associated with inefficiencies in the provision of banks' services. Banking sector distortions increase direct and indirect costs to the debtors: examples of these distortions include narrow restrictions on banks'

[9] The higher the credit need of an entrepreneur, the lower the interest rate on the loan must be for him to be able to undertake the project, according to equation (4.8). Banks will be less willing to give a credit, depressing the overall growth rate.

operations and services to clients (Demirgüç-Kunt and Maksimovic, 1998). One may argue that this "tax" applies equally to all energy firms operating in a given country, and not only to the RE producers represented in the model. However, energy firms in the conventional fossil fuel industry tend to be older and more established than RET firms, and may have greater means of using legal loopholes and institutional weaknesses to their advantage. Especially in regions where the economy depends on the income from the hydrocarbon extraction, refining and transportation industries, fossil fuel companies often have privileged access to local financing. Government policy should aim at providing a clear legal and institutional framework to create a more efficient banking sector, and at enforcing the rules which are put in place.

The second issue regards the potential creditor evaluation costs to banks $f$: the message is that better information on the available renewable energy technologies will foster the sector's development, i.e. an increase $N$. From energy sector surveys and firms' own accounts, it appears that renewable energy projects are at a particular disadvantage because of the short track record of the new energy technologies, high up-front costs, and relatively low returns spread out over long periods (Sonntag-O'Brien and Usher, 2004a,b). This implies higher information costs to the financier in order to properly assess the creditworthiness of the RE investment project. In addition, government policies favoring fossil energy producers, such as guarantees and special fiscal incentives, make the evaluation of a RET project *vis-à-vis* a fossil fuel project even less attractive and more costly for the financier.

The potential investors' evaluation costs can be reduced through public policy, e.g. by raising awareness and providing better information on new technologies and the risks and experiences connected with them. These costs can also be lowered more indirectly by eliminating tax breaks and other incentives granted to fossil fuel producers, or by setting up similar incentives for funding RE. The latter policy option would have a more direct positive effect on the fraction of creditworthy RE entrepreneurs $\phi$. There is also increasing experience of shared RE project funding through public-private partnerships

(PPPs), which can allow a cash-strapped government to mobilize complementary financing sources by mixing its experience in public-sector infrastructure and the reduced risk of partial governmental guarantees with private-sector commercial and financial experience.[10]

Bank concentration reduces financing opportunities in countries with less developed economies and institutions (Beck, 2003), making banking sector competition another policy goal for better-functioning credit allocation, which would affect both the distortional tax $\tau$ and the bank information costs $f$. An interesting alternative to traditional commercial banking, which also contributes to greater competition in financial intermediation, is venture capitalism (Rajan and Zingales, 2001). Venture capitalism has emerged as an important source of start-up investment finance, which could mitigate some of the difficulties involved with financing RE firms. However, the lack of well-developed legal frameworks and the generally greater political risk in developing and transition countries are two factors which reduce the investment attractiveness for venture capitalists, who rely on clear and enforceable contract laws and accounting standards to exercise their organizational rights and profit guarantees and, finally, their exit strategy.[11] The better institutions mentioned earlier could not only help increase competition in the traditional banking sector, but also attract new types of relationship-based financial intermediaries able to optimally evaluate credit potential.

Another policy implication is given by the primary resource-specific costs $\delta$: possibilities for intervention in this area are numerous. Based on the premise that different types of energy resources create different types of externalities, primary resource-specific costs could vary according to the prin-

[10] An example for a PPP is given by mezzanine funds, i.e. subordinated debt with a risk level somewhere between equity and bank debt.

[11] Whether or not a venture capitalist or even a market-based financial system should be preferred to a bank-based system is beyond the scope of this paper. For more on the debate of bank-based vs. market-based financial intermediation, see Levine and Zervos (1998).

ciple of internalizing externalities. The positive effect for RE firms of lower net production costs per unit $\delta$ also acts through the higher loan interest rate that they would be willing to pay to lenders (see equation 4.8). Benefits of renewable energy use can be priced in, for example by providing direct subsidies to RE firms or guaranteed feed-in costs into the national energy distribution grid for energy produced using new technologies, a system which has been successfully implemented for example in Germany. As economies of scale and learning effects reduce the costs associated with RETs, making them more competitive with fossil fuels, the incentives are gradually phased out.

In addition, a policy targeted at lowering production costs for RE would have an indirect effect on RE firms' access to bank financing. Government subsidies affect financial intermediaries' decisions through implicit or explicit backing of certain firms or sectors, leading in fact to a credit market distortion and more favorable lending terms (Demirgüç-Kunt and Maksimovic, 1999). Accordingly, in the model a subsidy decreasing $\delta$ would act as a government guarantee, lowering information costs $f$ for lenders and at the same time increasing the fraction of creditworthy RE firms $\phi$, and therefore pushing down the loan interest rate demanded by banks (see equation 4.11).

Finally, public policy can intervene to reduce the external financing $Z$ needed by RE firms, e.g. through grants and public facilities aimed at sharing project development and transaction costs (World Bank, 2002; Matsukawa et al., 2003; Sonntag-O'Brien and Usher, 2004a,b; UNEP, 2004). Governments in transition and developing countries may however not award a high priority to these policies, or simply not have the means to design and implement them. Advice and loans provided by international institutions can and have already been helpful, but risk creating situations of dependency and not being very effective or efficient in the long run.

## 4.4 Empirical evidence

The theoretical model presented above predicts that a better-developed financial sector will have a positive impact on the development of the renewable energy sector. The focus in particular has been on the importance of an unrestricted banking sector and of low information costs on RETs for financiers in order to foster the RE sector in transition and developing economies. This section presents an empirical framework to test these effects.

### 4.4.1 Method and data description

There has so far been only anecdotal evidence on the role of commercial finance in the development of RE. The lack of a more systematic empirical analysis of the correlation between financial sector and RE development is also due to the data problem regarding the quantification of the RE sector, especially in the developing world. The obstacles begin with the definition of RE in official statistics: traditionally, hydropower – mostly provided by large plants – has delivered the lion's share of renewable energy in countries' energy production mix, with other types of RE – when included – making up for barely a few percent of the overall energy production. Recently however, some environmentalists and policymakers have contended that large hydropower projects should not be viewed as viable contributions to sustainable energy production, as they often cause serious and substantial negative environmental and social externalities.

We consider these issues when testing the importance of financial intermediation for RET development by using two different dependent variables as proxies for RE sector development. The first, *reshare*, measures the overall RE share – including all types of hydro – in net total electricity generation. In a second series of estimations, we take into account the importance of large hydropower in electricity generation and their possible distorting effect on the results[12] by using the non-hydro RE share in net total electricity generation

[12] Most traditional, large hydro projects in the developing world have been co-financed

as the dependent variable (*geoshare*). This measure includes electricity produced from geothermal, solar, wind, and wood and waste energy resources. The data for both dependent variables is freely available from the U.S. Energy Information Administration (EIA). The covariates include four different indicators of financial sector development, and a vector of control variables, described below.

The data set provides an unbalanced panel for up to 118 non-OECD countries with observations for a maximum of 24 years (1980-2003). We perform generalized least squares (GLS) regressions for the equation

$$Y_{it} = \beta_1 + \beta_2 F_{it} + \beta_3 X_{it} + \omega_{it}, \tag{4.16}$$

where $Y_{it}$ is the dependent variable (*reshare* or *geoshare*) in country $i$ at time $t$, $F_{it}$ denotes the financial sector development variable, and $X_{it}$ the vector of control variables.[13] The composite error term $\omega_{it}$ consists of the country-specific error component $\epsilon_i$ and the combined cross-section and time series error component $u_{it}$, according to $\omega_{it} = \epsilon_i + u_{it}$.[14]

The financial sector development indicators are not direct measures of banks' efficiency in credit allocation, but rather different proxies for financial intermediary development tested in the literature. The first variable, *privcred*, captures the amount of credit provided by financial institutions to the private sector as a share of GDP. It excludes credits issued by governments and development banks. An unrestricted financial sector can be expected to account for a larger share of lending to the private sector. In fact, this

by multilateral financial institutions (MFIs) and the local governments, with little or no involvement sought of commercial finance (World Bank, 2003). The use of the overall RE share may therefore not only distort the results on the importance of the financial sector for more modern RETs, but in fact reverse them.

[13] Estimations were performed both with 1-year-lags for the financial indicators – as financial sector changes are not expected to have immediate effects – and 4-year-averages for all variables. For a detailed description of the variables and sources, see the Appendix.

[14] See for example Baltagi (2001) or Hsiao (2003) for an extensive discussion of panel data analysis models.

variable has been shown by Levine et al. (2000) to be a reliable measure of financial intermediary development, i.e. the ability of financial institutions to efficiently mobilize and allocate resources to profitable ventures. Earlier versions of the measure were used for example in King and Levine (1993a,b) and Levine and Zervos (1998). We expect *privcred* to correlate positively with the level of development of the RE sector.

The second variable, *commbank*, measures the importance of commercial banks' asset share versus that of the central bank, defined as the assets of deposit money banks over the sum of these assets plus those of the central bank. In more highly developed and open economies, the commercial financial sector handles a greater share of household savings than the central bank. Assuming that the commercial financial sector is more efficient than the public one in allocating credits, *commbank* should positively correlate with RET development. This variable has also been tested several times in the literature, e.g. in King and Levine (1993a,b) and Levine et al. (2000).

The third variable, *findep*, is a general measure of financial sector development commonly known as "financial depth", i.e. liquid liabilities of the financial system (generally M2) divided by GDP, which has been widely used in the literature on finance and growth since King and Levine (1993a,b). The present variable is based on the more sophisticated measure developed in Levine et al. (2000). The assumption is that the relative size of the financial intermediary sector is positively correlated with the quantity and quality of the financial services provided, and we would therefore expect a positive influence on the development of RETs.

The fourth and final financial sector variable, *finunder*, takes a different approach, measuring financial *underdevelopment* or *repression* as the ratio of reserve holdings to liquidity. A high reserve ratio is expected to have a negative impact on the amount of assets available for credit allocation and consequently the development of RETs, since "a high coefficient of required reserve for commercial banks will force them to hold a greater amount of non-interest bearing monetary reserves" (Roubini and Sala-i-Martin, 1992:

25).

Our main control variable *psreform* describes the level of power sector reform in developing and transition countries. It is based on a broad qualitative survey by the World Bank conducted in 1998 (ESMAP, 1999) and takes on values from 0 (least reformed) to 6 (reforms in all relevant areas have been implemented). The evaluation considers measures to create equal market opportunities for all energy resource types and encourage private firms' participation and competition. Hence, *psreform* is a proxy for government energy policies. As discussed in the previous section, the institutional framework is a crucial element of financiers' information costs on RETs (i.e. $f$ in the theoretical model), signalling a government's commitment to leveling the playing field for energy providers and thereby reducing uncertainty about future profitability of a RE project. Since there is no reliable data available on creditor evaluation costs in less developed economies, this crude proxy will have to suffice. We expect a positive impact of power sector reforms on the RE sector, particularly on the share of non-hydro RE.

Several other control variables are included.[15] Official development assistance by multilaterals (*oda*) aims to control for the effect of multilateral donor money, while foreign direct investment (*fdi*) and net domestic investment (*inv*) capture general private investment in a country (*inv* being the more complete measure, including portfolio investments and financial derivatives as well as foreign and domestic capital and equity investment). Further variables include regional and period dummies (for the 4-year average estimations); initial real GDP per capita; and a measure of economic development (*devind*) ranging from 1 to 4 based on the World Bank classification of low, lower middle, middle, and high income countries according to 2003 GNI. Finally, we control for the possible exogenous effects on RE development of the costs of non-renewable energy resource production by including the average

[15] Unfortunately, there is not enough cross-country data available on RE *potential* to provide a useful control variable. However, we believe that this does not greatly bias our results given the range of RETs considered.

annual market price of crude oil. If the price of the most common conventional fuel affects investment in alternative energy sources, we would expect a positive effect of an oil price increase on the share of RE in power production.

### 4.4.2 Estimation results

It is of particular interest to observe the sign and statistical validity of the financial sector coefficients $\beta_2$ rather than their actual magnitude, given the quality of the data for the RE sector. The aim is to observe whether the development of the RE sector is positively influenced by the financial intermediary sector, and especially by the banking system.

Table 4.1 reports the results for random-effects regressions on the full sample[16] for RE share (panel A) and non-hydro RE share (panel B). It is apparent that the four financial sector variables are statistically significant when regressed on both measures of RE sector development, and that they are fairly robust to controlling for other effects both regarding their statistical significance and the magnitude of their coefficients. *findep* and *privcred* generally prove more reliable, while *finunder* has the weakest explanatory power, with *commbank* situated in between.

It is however interesting that the signs of the four coefficients are consistently opposite when estimating with *reshare* versus *geoshare* as dependent variables. When considering non-hydro RE share (panel B), the signs correspond to those predicted by the theory, namely that financial sector development has a positive effect on the development of RETs. When hydropower is included in the estimations, the situation changes round completely, confirming the inherent difficulty surmised above in including mostly MFI-financed (large) hydro in the sample. This hypothesis receives further support through the high significance of the economic development indicator *devind* observed

[16] Both random-effects and fixed-effects estimations were performed on all variables for the lagged sample and the 4-year averages. As the Hausman test showed no clear advantage of using fixed effects, only random-effects estimation results are shown. See Baltagi (2001) for more details on the Hausman specification test.

Table 4.1: Financial development and the share of renewable energy resources in total net electricity generation in non-OECD countries

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| *Panel A* | | | | | | | | |
| *Dep't variable* | | | | | | | | |
| *is reshare* | | | | | | | | |
| logfindep | $-4.43^{***}$ | $-4.36^{***}$ | | | | | | |
| | (0.76) | (0.76) | | | | | | |
| logprivcred | | | $-0.87^{***}$ | $-0.85^{***}$ | | | | |
| | | | (0.31) | (0.31) | | | | |
| logcommbank | | | | | $-7.45^{***}$ | $-7.52^{***}$ | | |
| | | | | | (1.21) | (1.33) | | |
| logfinunder | | | | | | | $1.19^{***}$ | $1.01^{***}$ |
| | | | | | | | (0.31) | (0.39) |
| logfdi | $-0.67^{***}$ | $-0.64^{***}$ | | | $-1.06^{***}$ | $-0.86^{***}$ | | $-0.912^{***}$ |
| | (0.18) | (0.18) | | | (0.23) | (0.24) | | (0.18) |
| devind | | $-9.95^{***}$ | | $-8.48^{**}$ | $-8.85^{**}$ | | $-10.71^{**}$ | $-9.08^{**}$ |
| | | (3.63) | | (3.98) | (3.73) | | (4.22) | (4.25) |
| eefsudummy | | $-24.13^{***}$ | $-22.77^{***}$ | $-20.89^{***}$ | | $-20.08^{**}$ | $-13.98^{*}$ | $-14.14^{*}$ |
| | | (-24.13) | (8.16) | (8.14) | | (8.86) | (8.26) | (8.33) |
| oilprice | | 0.02 | | 0.01 | | $-0.04$ | 0.05 | |
| | | (0.04) | | (0.04) | | (0.04) | (0.04) | |
| $R^2$ | 0.22 | 0.15 | 0.12 | 0.16 | 0.15 | 0.19 | 0.14 | 0.14 |
| N | 1541 | 1541 | 1883 | 1883 | 1203 | 1031 | 2077 | 1629 |
| *Panel B* | | | | | | | | |
| *Dep't variable* | | | | | | | | |
| *is geoshare* | | | | | | | | |
| logfindep | $0.52^{***}$ | $0.49^{***}$ | | | | | | |
| | (0.17) | (0.17) | | | | | | |
| logprivcred | | | $0.22^{***}$ | $0.21^{**}$ | | | | |
| | | | (0.08) | (0.08) | | | | |
| logcommbank | | | | | $0.49^{**}$ | $0.42^{**}$ | | |
| | | | | | (0.22) | (0.2) | | |
| logfinunder | | | | | | | $-0.13^{*}$ | $-0.13^{*}$ |
| | | | | | | | (0.08) | (0.08) |
| psreform | $0.54^{***}$ | $0.54^{***}$ | $0.53^{***}$ | $0.53^{***}$ | 0.44 | $0.45^{**}$ | $0.53^{***}$ | $0.44^{**}$ |
| | (0.18) | (0.20) | (0.18) | (0.20) | (0.27) | (0.2) | (0.18) | (0.19) |
| logoda | | | | | $0.27^{***}$ | $0.19^{***}$ | $0.18^{***}$ | $0.19^{***}$ |
| | | | | | (0.07) | (0.06) | (0.06) | (0.06) |
| devind | | | | | | -0.18 | $-0.21$ | |
| | | | | | | (0.54) | (0.5) | |
| eefsudummy | | $-2.47^{**}$ | | $-2.44^{**}$ | $-3.15$ | $-2.52^{**}$ | | $-2.543^{***}$ |
| | | (1.02) | | (1.02) | (2.15) | (0.99) | | (0.97) |
| oilprice | | 0.00 | | 0.01 | | 0.01 | | 0.01 |
| | | (0.00) | | (0.01) | | (0.01) | | (0.01) |
| $R^2$ | 0.07 | 0.11 | 0.09 | 0.13 | 0.12 | 0.13 | 0.08 | 0.13 |
| N | 1125 | 1125 | 1053 | 1053 | 1118 | 1352 | 1346 | 1346 |

*Notes*: All regressions are random-effects GLS on full sample panel of 118 non-OECD countries from 1980-2003 with 1-year-lags in financial indicators. Regressions were also performed for 4-year average data, which yielded very similar results and are not reported here. Other control variables are not listed as they proved insignificant. Standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively. Joint significance tests strongly reject hypothesis of no difference between covariates in all estimations. For detailed variable descriptions and sources see the Appendix, Table 4.3.

in panel A.[17] If it is true that development banks in the past favored large hydro projects, then we would indeed expect to find a negative relationship between economic development and the overall RE share. The economic development effect loses significance when considering only non-hydro RE (panel B).

Regarding the other variables in Table 4.1, we find a significant and robust positive effect of power sector reforms on the share of non-hydro RE (panel B), confirming the hypothesis that policies aimed at leveling the playing field for all energy types encourage the development of RETs (other than large hydropower projects). For a certain institutional framework in the power sector, the financial development coefficients consistently show the expected signs with a high level of significance.

It is also interesting to note the effect of including regional dummies in the estimations (with Asia and Oceania being the omitted regional dummy). Eastern European and former Soviet Union countries (*eefsudummy*) have a consistently lower share of all types of RE, especially of non-hydro RE. This can be explained by the decades of socialist energy policy favoring the use of fossil fuels in electricity generation and energy production in general. The other regional dummies were not statistically significant. Last but not least, the inclusion of oil prices had no significant effect on the magnitude or error margin of the other variables. With one exception, oil prices had the expected positive sign, but proved statistically insignificant in both estimation series. World oil price fluctuations do not appear to have had a noticeable influence on RE development during the time period observed.

In sum, the results of the empirical analysis support the basic hypothesis from the theoretical model that financial intermediary development encourages the growth of the RE sector, especially when limiting the estimations to non-hydro RETs. The findings are also quite robust to the inclusion of other covariates which could influence RE sector development. But further

[17] Initial real GDP per capita had a similar effect. For simplicity, only the results using the economic development indicator are shown.

empirical research is needed to corroborate these results, as they very likely suffer from measurement errors due to the quality of the available RE data.

## 4.5 Conclusions

The paper examines the determinants of credit allocation to renewable energy firms in developing and transition countries. It develops a multi-sector endogenous growth model to explain the financing problems of renewable energy (RE) projects in these countries. Growth in the model stems from the diversification of the primary RE production sector, i.e. the use of a more varied range of renewable energy technologies (RETs) in energy production. Energy production today relies on exhaustible and polluting conventional fossil fuels, and a larger share of alternative energy sources in primary energy production would not only have positive environmental effects, but would also bring greater energy security for future generations, as RETs exploit domestic renewable energy resources. Diversification in the use of RETs is hence assumed to be beneficial for a sustainable energy sector.

Energy firms in less developed economies are largely dependent on external financing to realize new projects; in turn, external financing in these countries relies on the banking sector, as stock markets and venture capitalism are not well enough established to provide large-scale funding. However, the underdevelopment of the banking sector, in addition to specific RE-sector problems such as high up-front and information costs and long lead times, hamper the emergence of RE entrepreneurs. The steady-state equilibrium solution yields several results: less banking sector distortion and lower evaluation costs to potential creditors will increase growth rates, while higher external financing needs by the RE firm will lower growth rates.

Several policy recommendations for the emergence of RETs are derived: general banking sector development through creating better legal and institutional frameworks, as well as the more targeted provision of information on new energy technologies. Specific measures aimed at reducing the relative price of RE production through taxes or fixed feed-in prices (to include positive externalities) are also considered, as well as the merit of public-private partnerships to lower project costs for generators and the perceived risk for financiers. In short, there are many ways of leveling the playing field for new energy technologies. The subsidy option should however be a temporary instrument to boost the development of a sustainable energy sector and future energy security. As new energy technologies take off, scale and learning effects will ensure their market success.

The positive effect of financial sector development on the development of RETs found in the theoretical model is tested empirically. The results are encouraging: all four variables measuring financial intermediary development are significant and have the expected signs. In addition, energy sector reforms also have a significant positive effect. The results are fairly robust to the addition of other control variables – including world oil prices, which appear to have no impact on RE sector development.

The approach is a first attempt at modeling and empirically verifying the financing difficulties facing the renewable energy industry. The availability of quality data on RE development and investment has so far hampered empirical studies in this area; further work is needed to corroborate the results. An interesting extension for future research is the role that financial intermediaries play in the substitution of fossil fuels in favor of RE.

## 4.6 Appendix

Table 4.2: Descriptive statistics of main variables

| **Variable** | **Obs.** | **Mean** | **Std. Dev.** | **Min.** | **Max.** |
|---|---|---|---|---|---|
| reshare | 2497 | 47.53 | 34.67 | 0.01 | 100 |
| geoshare | 2497 | 1.21 | 4.08 | 0 | 40.18 |
| findep | 2726 | 37.41 | 24.71 | 0.00 | 168.85 |
| privcred | 2607 | 25.55 | 22.56 | 0.00 | 151.77 |
| commbank | 3008 | 74.07 | 23.68 | 2.98 | 136.59 |
| finunder | 3069 | 26.55 | 128.44 | −13.24 | 5017.639 |
| psreform | 115 | 2.04 | 2.09 | 0 | 6 |
| oilprice | 24 | 22.62 | 6.46 | 12.72 | 35.69 |

# Table 4.3: Variables and sources

All data were collected for non-OECD countries (as of 1980 – the recent OECD members Czech Republic, Hungary, Korea, Mexico, Poland, and Slovakia were included in the estimations) for the years 1980-2003 (where available).

| **Variable** | **Definition** | **Source** |
|---|---|---|
| reshare | Share of renewable energies – including hydro, wood and waste, geothermal, solar, and wind – in net total electricity generation | EIA |
| geoshare | Share of non-hydro renewable energies – including geothermal, wind, solar, and wood and waste – in net total electricity generation | EIA |
| findep | Financial depth measured by $100^*(0.5^*(M2_i(t) + M2_i(t-1))/GDP(t))$ where $M2$ is liquid liabilities (lines 34+35) and $GDP$ is line 99b | IFS |
| privcred | Credit by financial institutions to the private sector as share of GDP, measured by $100^*(0.5^*(CREDIT(t) + CREDIT(t-1)))/GDP)$ with $CREDIT$ being total private sector credit allocations by deposit money banks and other financial institutions (lines 22d+42d) and GDP line 99b | IFS |
| commbank | Commercial bank asset share versus central bank, measured by $100^*(DBA(t)/(DBA(t) + CBA(t)))$ where $DBA$ is assets of deposit money banks (lines 22a-d) and $CBA$ is assets of the central bank (lines 12a-d) | IFS |
| finunder | Financial underdevelopment or repression measured by $100^*(COMM(t)/M2(t))$ where $COMM$ is commercial bank reserves (line 20) and $M2$ is liquid liabilities (lines 34+35) | IFS |
| oda | Official development assistance and official aid – disbursements by multilaterals | OECD |
| fdi | Foreign direct investment (line 78bed) | IFS |
| inv | Net sum investment in economy, including direct investment, portfolio investment, financial derivatives, and other investment (line 78bjd) | IFS |
| cgdp | Per capita real GDP in 1980 | PWT 6.1 |
| devind | Development indicator based on the World Bank classification of countries by income (2003 GNI) from low (1) to high income (4) | World Bank |
| psreform | Qualitative power sector reform indicator for 1998, ranging from 0 (no reforms) to 6 (all relevant reforms implemented in all areas) | ESMAP(1999) |
| oilprice | Crude oil prices measured in USD per barrel, in current dollars, from 1980-2003 | British Petroleum |

# References

Acemoglu, D. and S. Johnson (2005). Unbundling institutions. *Journal of Political Economy* 113: 949-995.

Acemoglu, D., Johnson, S., and J.A. Robinson (2001). The colonial origins of comparative development: an empirical investigation. *American Economic Review* 91: 1369-1401.

Acemoglu, D., S. Johnson, and J.A. Robinson (2002). Reversal of fortune: geography and institutions in the making of the modern world income distribution. *Quarterly Journal of Economics* 117: 1231-1294.

Alesina, A. and D. Rodrik (1994). Distributive politics and economic growth. *Quarterly Journal of Economics* 108: 465-490.

Alesina, A., Devleeschauwer, A., Easterly, W., Kurlat, S., and R. Wacziarg (2003). Fractionalization. *Journal of Economic Growth* 8: 155-194.

Alexeev, M. and R. Conrad (2005). The elusive curse of oil. Duke University, Terry Sanford Institute of Public policy, Working Paper Series SAN05-07.

Anand, S. and S. Kanbur (1993a). The Kuznets process and the inequality-development relationship. *Journal of Development Economics* 40: 25-52.

Anand, S. and S. Kanbur (1993b). Inequality and development: A critique. *Journal of Development Economics* 41: 19-43.

Andersen, J. and S. Aslaksen (2006). Constitutions and the resource curse. Norwegian University of Science and Technology, NTNU, Department of Economics, Discussion Paper.

Atkinson, A.B. and A. Brandolini (2001). Promises and pitfalls in the use of secondary data-sets: income inequality in OECD countries as a case study. *Journal of Economic Literature* 39 (3): 771-800.

Atkinson, G. and K. Hamilton (2003). Savings, growth and the resource curse hypothesis. *World Development* 31: 1793-1807.

Auty, R.M. (1997). Natural resource endowment, the state and development strategy. *Journal of International Development* 9: 651-663.

Auty, R.M. (2001). The political economy of resource-driven growth. *European Economic Review* 45: 839-846.

Babbar, S. and J. Schuster (1998). Power project finance: experience in developing countries. World Bank RMC Discussion Paper No. 119.

Baker, M.J. (2003). An equilibrium model of land tenure in hunter-gatherer societies. *Journal of Political Economy* 111: 124-173.

Baland, J.M. and P. Francois (2000). Rent seeking and resource booms. *Journal of Development Economics* 61: 527-542.

Baldwin, R.E. (1956). Patterns of development in newly settled regions. *The Manchester School of Economic and Social Studies* XXIV: 161-179.

Baltagi, B. H. (2001). *Econometric analysis of panel data*. Chichester, UK: John Wiley & Sons, 2nd Edition.

Barbier, E.B. (2005a). Natural resource-based economic development in history. *World Economics* 6 (3): 103-152.

Barbier, E.B. (2005b). *Natural resources and economic development*. Cambridge: Cambridge University Press.

Barro, R.J. and J.-W. Lee (2001). International data on educational attainment: updates and implications. *Oxford Economic Papers* 53: 541-563.

Barro, R.J. and X. Sala-i-Martin (2004). *Economic growth*. Cambridge, MA: MIT Press, 2nd Edition.

Beck, T. (2003). Financial dependence and international trade. *Review of International Economics* 11 (2): 296-316.

Beck, T., A. Demirgüç-Kunt, and V. Maksimovic (2004a). Bank competition and access to finance: international evidence. *Journal of Money, Credit, and Banking* 36 (3): 627-48.

Beck, T., A. Demirgüç-Kunt, and V. Maksimovic (2004b). The determinants of financing obstacles. World Bank Policy Research Working Paper No. 3204.

Beck, T., G. Clarke, A. Groff, P. Keefer, and P. Walsh (2005). New tools in comparative political economy: The Database of Political Institutions. *World Bank Economic Review* 15: 165-176.

Black, J. (1995). A Military Revolution? In C.J. Rogers (ed). *The Military Revolution debate: Readings on the military transformation of early modern Europe*. Boulder, CO: Westview Press.

Bohn, H. and R.T. Deacon (2000). Ownership risk, investment and the use of natural resources. *American Economic Review* 90: 526-549.

Bolton, H.E. and T.M. Marshall (1920). *The colonization of North America 1492-1783*. New York: Macmillan.

Boschini, A.D., J. Pettersson, and J. Roine (2004). Resource curse or not: a question of appropriability. Stockholm University, Department of Economics, mimeo.

Bourguignon, F. and C. Morrisson (1998). Inequality and development: The role of dualism. *Journal of Development Economics* 57: 233-257.

Bourguignon, F. and T. Verdier (2000). Oligarchy, democracy, inequality and growth. *Journal of Development Economics* 62: 285-313.

Bravo-Ortega, C. and J. De Gregorio (2005). The relative richness of the poor? Natural resources, human capital and economic growth. World Bank Working Paper Series, No. 3484.

Brunnschweiler, C.N. (2008). Cursing the blessings? Natural resource abundance, institutions, and economic growth. *World Development*, in press.

Brunnschweiler, C.N. and E.H. Bulte (2008). The resource curse revisited an revised: a tale of paradoxes and red herrings. *Journal of Environmental Economics and Management*, forthcoming.

Buckley, K. (1958). The role of staple industries in Canada's economic development. *The Journal of Economic History* 18 (4): 439-450.

Bulte, E.H., R. Damania, and R.T. Deacon (2005). Resource intensity, institutions, and development. *World Development* 33: 1029-1044.

Cable, J. (1998). *The political influence of naval force in history*. London: Macmillan Press.

Carlin, W. and C. Mayer (2003). Finance, investment and growth. *Journal of Financial Economics* 69 (1): 191-226.

Chambers, E.J. and D.F. Gordon (1966). Primary products and economic growth: an empirical measurement. *Journal of Political Economy* 74 (4): 315-332.

Chambers, E.J. and D.F. Gordon (1967). Primary products and economic growth: rejoinder. *Journal of Political Economy* 75 (6): 881-885.

Chamley, C. and P. Honohan (1990). Taxation of financial intermediation: measurement principles and application to five African countries. World Bank Policy, Research and External Affairs Working Paper No. 421.

Chand, S. and K. Moene (1999). Controlling fiscal corruption. *World Development* 27: 1129-1140.

Churchill, A.A. and R.J. Saunders (1989). Financing of the energy sector in developing countries. World Bank Industry and Energy Department Working Paper, Energy Series Paper No. 14.

Clarida, R.H. and R. Findlay (1992). Government, Trade and Comparative Advantage. *American Economic Review (Papers and Proceedings)* 82: 122-127.

Clarke, G. (1995). More evidence on income distribution and growth. *Journal of Development Economics* 47: 403-428.

Coatsworth, J.H. (1999). Economic and institutional trajectories in 19th century Latin America. In J.H. Coatsworth and A.M. Taylor (eds.). *Latin America and the world economy since 1800*. Cambridge, MA: Harvard University Press.

Collier, P. and A. Hoeffler (1998). On economic causes of civil war. *Oxford Economics Papers* 50: 563-573.

Collier, P. and A. Hoeffler (2005). Resource rents, governance, and conflict. *Journal of Conflict Resolution* 49: 625-633.

Dales, J.H., J.C. McManus, and M.H. Watkins (1967). Primary products and economic growth: a comment. *Journal of Political Economy* 75 (6): 876-880.

Davis, G.A. (1995). Learning to love the Dutch disease: evidence from the mineral economies. *World Development* 23: 1765-1779.

Davis, G.A. (1998). The minerals sector, sectoral analysis, and economic development. *Resources Policy* 24: 217-228.

Deininger, K. and L. Squire (1996). A new data set measuring income inequality. *World Bank Economic Review* 10 (3): 565-591.

Deininger, K. and L. Squire (1998). New ways of looking at old issues: inequality and growth. *Journal of Development Economics* 57 (2): 259-287.

Del Mar, A. (1902). *A history of the precious metals from the earliest times to the present*. New York: Burt Franklin, 2nd edition.

Demirgüç-Kunt, A. and V. Maksimovic (1998). Law, finance, and firm growth. *The Journal of Finance* 53 (6): 2107-37.

Demirgüç-Kunt, A. and V. Maksimovic (1999). Institutions, financial markets, and firm debt maturity. *Journal of Financial Economics* 54: 295-336.

Ding, N. and B.C. Field (2005). Natural resource abundance and economic growth. *Land Economics* 81: 496-502.

Easterly, W. (2007). Inequality does cause underdevelopment: Insights from a new instrument. *Journal of Development Economics* 84 (2): 755-776.

Easterly, W. and R. Levine (1997). Africa's growth tragedy: policies and ethnic divisions. *Quarterly Journal of Economics* 112: 1203-1250.

EIA, Energy Information Administration (2000). Long term world oil supply. Presentation prepared for the American Association of Petroleum Geologists. Available at http://www.eia.doe.gov/.

Engerman, S.L., and K.L. Sokoloff (1997). Factor endowments, institutions, and differential paths of growth among New World economies. In S.H. Haber (ed.). *How Latin America fell behind*. Stanford, CA: Stanford University Press.

Engerman, S.L., and K.L. Sokoloff (2002). Factor endowments, inequality, and paths of development among New World economies. NBER Working Paper No. 9259.

ESMAP (1999). Global energy sector reform in developing countries: a scorecard. World Bank, Vol. 1, ESM219 (July 99).

Fazzari, S.M., R.G. Hubbard, and B.C. Petersen (1988). Financing constraints and corporate investment. *Brookings Papers on Economic Activity* 1988 (1): 141-206.

Ferguson, N. (2002). *Empire: the rise and demise of the British world order and the lessons for global power*. London: Allen Lane.

Ferro, M. (1997). *Colonization: a global history*. London: Routledge.

Findlay, R. and M. Lundahl (1994). Natural resources, "vent-for-surplus", and the staples theory. In G. Meier (ed.). *From classical economics to development economics: Essays in honor of Hla Myint*. New York, NY: St. Martin's Press.

Findlay, R. and M. Lundahl (2001). Natural resources and economic development: the 1870-1914 experience. In R.M. Auty (ed.). *Resource abundance and economic development*. Oxford: Oxford University Press.

Förster, S., W.J. Mommsen, and R. Robinson (eds.) (1988). *Bismarck, Europe, and Africa: the Berlin Africa Conference 1884-1885 and the onset of partition*. Oxford: Oxford University Press.

Forbes, K. (2000). A reassessment of the relationship between inequality and growth. *American Economic Review* 90: 869-887.

Frankel, J.A. and D. Romer (1999). Does trade cause growth? *American Economic Review* 89: 379-399.

Gallup, J.L., J.D. Sachs, and A.D. Mellinger (1999). Geography and economic development. *International Regional Science Review* 22: 179-232.

Gellar, S. (1995). The colonial era. In P.M. Martin and P. O'Meara (eds.). *Africa*. Bloomington, IN: Indiana University Press, 3rd edition.

Giovannini, A. and M. de Melo (1993). Government revenue from financial repression. *American Economic Review* 83 (4): 953-63.

Glaeser, E.L., R. La Porta, F. Lopez-De-Silanes, and A. Shleifer (2004). Do institutions cause growth? *Journal of Economic Growth* 9: 271-303.

Glete, J. (ed.) (2005). *Naval history 1500-1680*. Aldershot: Ashgate.

Grant, D. (1974). The staple theory and its empirical measurement. *Journal of Political Economy* 82 (6): 1249-1253.

Green, A. and M.C. Urquhart (1976). Factor and commodity flows in the international economy of 1870-1914: a multi-country view. *Journal of Economic History* 36: 217-252.

Greene, W.H. (2003). *Econometric analysis*. Upper Saddle River, NJ: Prentice-Hall, 5th edition.

Gries, T., G. Sievert, and A. Wieneke (2004). Interbank market frictions, international banks and growth. *International Economics and Economic Policy* 1 (2-3): 157-171.

Grossman, H. and M. Kim (1995). Swords or plowshares: A theory of the security to claims of property. *Journal of Political Economy* 103: 1275-1288.

Guilmartin, J.F., Jr. (1995). The Military Revolution: origins and first tests abroad. In C.J. Rogers (ed). *The Military Revolution debate: readings on the military transformation of early modern Europe*. Boulder: Westview Press.

Gwartney, J. and R. Lawson (2005). *Economic Freedom of the World: 2005 annual report*. Vancouver: The Fraser Institute.

Gylfason, T. (2001). Natural resources, education, and economic development. *European Economic Review* 45: 847-859.

Hall, R.E. and C.I. Jones (1999). Why do some countries produce so much more output per worker than others? *Quarterly Journal of Economics* 114: 83-116.

Hansen, B.E. (2000). Sample splitting and threshold estimation. *Econometrica* 68: 575-603.

Harford, T. and M. Klein (2005). Aid and the resource curse. Washington, D.C.: The World Bank Group, Private Sector Development Vice Presidency, Note No. 291.

Hausmann, R. and R. Rigobon (2002). An alternative interpretation of the resource curse: theory and policy implications. NBER Working Paper, No. 9424.

Head, C. (2000). Financing of private hydropower projects. World Bank Discussion Paper No. 420.

Hirschleifer, J. (1995). Anarchy and its breakdown. *Journal of Political Economy* 103: 26-52.

Hirschman, A.O. (1958). *The strategy of economic development*. New Haven, CT: Yale University Press.

Hodler, R. (2006). The curse of natural resources in fractionalized countries. *European Economic Review* 50: 1367-1386.

Holmes, K.R., M. Miles, and M.A. O'Grady (2006). *2006 Index of Economic Freedom.* Washington, D.C.: The Heritage Foundation.

Hsiao, C. (2003). *Analysis of panel data*. Cambridge: Cambridge University Press.

IEA, International Energy Agency (2003). *World Energy Investment Outlook, 2003 Insights*. Paris: International Energy Agency.

IEA, International Energy Agency (2005). *World Energy Outlook*. Paris: International Energy Agency.

IGS, Institute of Geological Sciences (1978). *World mineral statistics 1970-1974: production, exports, imports.* London: Her Majesty's Stationery Office.

Innis, H. (1930). *The fur trade in Canada: an introduction to Canadian economic history*. New Haven, CT: Yale University Press.

Innis, H. (1940). *The cod fisheries: the history of an international economy.* New Haven, CT: Yale University Press.

Isham, J., L. Pritchett, M. Woolcock, and G. Busby (2005). The varieties of resource experience: natural resource export structures and the political economy of economic growth. *World Bank Economic Review* 19: 141-174.

Ishiguro, M. and T. Akiyama (1995). Electricity demand in Asia and the effects on energy supply and the investment environment. World Bank Policy Research Working Paper No. 1557.

Jensen, N. and L. Wantchekon (2004). Resource wealth and political regimes in Africa. *Comparative Political Studies* 37: 816-841.

Kaldor, N. (1956). Alternative theories of distribution. *Review of Economic Studies* 23: 94-100.

Karl, T. (1997). *The paradox of plenty: Oil booms and petro-states*. Berkeley: University of California Press.

Kaufmann, D., A. Kraay, and M. Mastruzzi (2005). Governance Matters IV: governance indicators for 1996-2004. World Bank Policy Research Working Paper Series 2005, No. 3630.

Keim, C.A. (1995). Africa and Europe before 1900. In P.M. Martin and P. O'Meara (eds.). *Africa*. Bloomington, IN: Indiana University Press, 3rd edition.

Kellenbenz, H. (ed.) (1981). *Precious metals in the age of expansion*. Stuttgart: Klett-Cotta.

Kennedy, P. (2003). *A guide to econometrics*. Oxford: Blackwell Publishing, 5th edition.

King, R.G. and R. Levine (1993a). Finance and growth: Schumpeter might be right. *Quarterly Journal of Economics* 108: 717-38.

King, R.G. and R. Levine (1993b). Finance, entrepreneurship, and growth. *Journal of Monetary Economics* 32: 513-42.

Knack, S. and P. Keefer (1995). Institutions and economic performance: cross-country tests using an alternative institutional measures. *Economics and Politics* 7: 207-227.

Kuznets, S. (1955). Economic growth and income inequality. *American Economic Review* 45: 1-28.

La Porta, R., F. Lopez-de-Silanes, A. Shleifer, and R. Vishny (1997). Legal determinants of external finance. *The Journal of Finance* 52 (3): 1131-1150.

La Porta, R., F. Lopez-de-Silanes, A. Shleifer, and R. Vishny (1999). The quality of government. *Journal of Law, Economics, & Organization* 15: 222-278.

Ledermann, D. and W.F. Maloney (2003). Trade structure and growth. World Bank Policy Research Working Paper, No. 3025.

Leite, C. and J. Weidmann (2002). Does Mother Nature corrupt? Natural resources, corruption and economic growth. In G. Abed and S. Gupta (eds.). *Governance, corruption, and economic performance*. Washington, D.C.: International Monetary Fund, 159-196 (Ch. 7).

Levine, R. and S. Zervos (1998). Stock markets, banks, and economic growth. *American Economic Review* 88 (3): 537-58.

Levine, R., N. Loayza, and T. Beck (2000). Financial intermediation and growth: causality and causes. *Journal of Monetary Economics* 46 (1): 31-77.

Lewis, W. (1954). Economic development with unlimited supplies of labor. *The Manchester School of Economics and Social Studies* XXII: 139-191.

Louis, W.R. (ed.) (1976). *Imperialism: the Robinson and Gallagher controversy*. New York: Franklin Watts.

Lynn, J.A. (1991). Clio in arms: the role of the military variable in shaping history. *Journal of Military History* 55 (1): 83-95.

Manzano, O. and R. Rigobon (2001). Resource curse or debt overhang? NBER Working Paper, No. 8390.

Mariscal, E. and K.L. Sokoloff (2000). Schooling, suffrage, and the persistence of inequality in the Americas, 1800-1945. In S. Haber (ed.). *Political institutions and economic growth in Latin America: Essays in policy, history, and political economy*. Stanford, CA: Hoover Institution Press.

Marshall, M.G. and K. Jaggers (2002). Polity IV Project: political regime characteristics and transitions, 1800-2002. http://www.cidcm.umd.edu/inscr/polity.

Matsen, E. and R. Torvik, 2005. Optimal Dutch disease. *Journal of Development Economics* 78: 494-515.

Matsukawa, T., R. Sheppard, and J. Wright (2003). Foreign exchange risk mitigation for power and water projects in developing countries. World Bank Energy and Mining Sector Board Discussion Paper No.9.

Matsuyama, K. (1992). Agricultural productivity, comparative advantage and economic growth. *Journal of Economic Theory* 58: 317-334.

Mauro, P. (1995). Corruption and growth. *Quarterly Journal of Economics* 110: 681-712.

McEvedy, C. and R. Jones (1978). *Atlas of world population history.* London: Lane.

Mehlum, H., K. Moene, and R. Torvik (2006). Institutions and the resource curse. *Economic Journal* 116: 1-20.

Miguel, E, S. Satyanath, and E. Sergenti (2004). Economic shocks and civil conflict: an instrumental variables approach. *Journal of Political Economy* 112: 725-753.

Mookherjee, D. (1997). Wealth effects, incentives and productivity. *Review of Development Economics* 1: 116-133.

Myint, H. (1958). The "classical theory" of international trade and the underdeveloped countries. *Economic Journal* 68 (270): 317-337.

Neumayer, E. (2004). Does the "resource curse" hold for growth in genuine income as well? *World Development* 32: 1627-1640.

Norman, C. (2006). Rule of law and the resource curse: abundance versus intensity? Johns Hopkins University, mimeo.

North, D.C. (1961). *The economic growth of the United States, 1790-1860.* Englewood Cliffs, NJ: Prentice-Hall.

North, D.C., W. Summerhill, and B. Weingast (2000). Order, disorder and economic change: Latin America vs. North America. In B. Bueno de Mesquita and H.L. Root (eds.). *Governing for prosperity*. New Haven, CT: Yale University Press.

Papyrakis, E. and R. Gerlagh (2004). The resource curse hypothesis and its transmission channels. *Journal of Comparative Economics* 32: 181-193.

Parker, G. (1996). *The military revolution: military innovation and the rise of the West 1500-1800*. New York: Cambridge University Press, 2nd edition.

Persson, T. and G. Tabellini (1994). Is inequality harmful for growth? *American Economic Review* 84: 600-621.

Persson, T. and G. Tabellini (2003). The economic effects of constitutions: what do the data say? Cambridge MA: MIT Press.

Persson, T. and G. Tabellini (2004). Constitutional rules and fiscal policy outcomes. *American Economic Review* 94: 25-46.

Persson, T. and G. Tabellini (2005). *The economic effects of constitutions*. Cambridge MA: MIT Press.

Persson, T., G. Roland, and G. Tabellini (2000). Comparative politics and public finance. *Journal of Political Economy* 108: 1121-1141.

Prebisch, R., 1950. *The economic development of Latin America and its principal problems*. New York: United Nations.

Przeworski, A. and F. Limongi (1993). Political regimes and economic growth. *Journal of Economic Perspectives* 7: 51-69.

Rajan, R.G. and L. Zingales (2001). Financial dependence and growth. *Oxford Review of Economic Policy* 88 (3): 559-86.

Roberts, M. (1995). The Military revolution, 1560-1660. In C.J. Rogers, Jr. (ed.). *The military revolution debate: readings on the military transformation of early modern Europe*. Boulder: Westview Press.

Robinson, R. (1972). Non-European foundations of European imperialism: sketch for a theory of collaboration. In E.R.J. Owen and R.B. Sutcliffe, (eds.). *Studies in the theory of imperialism*. London: Longman.

Robinson, J.A., R. Torvik, and T. Verdier (2006). The political foundations of the resource curse. *Journal of Development Economics* 79: 447-468.

Rodriguez, F. and J.D. Sachs (1999). Why do resource-abundant economies grow more slowly? *Journal of Economic Growth* 4: 277-303.

Rodrik, D. (2001). The global governance of trade as if development really mattered. Trade and Human Development Series, New York: UNDP.

Rodrik, D., A. Subramanian, and F. Trebbi (2004). Institutions rule: the primacy of institutions over geography and integration in economic development. *Journal of Economic Growth* 9: 131-165.

Rogers, C.J., Jr. (ed.) (1995). *The Military Revolution debate: readings on the military transformation of early modern Europe*. Boulder: Westview Press.

Romer, P.M. (1990). Endogenous technological change. *Journal of Political Economy* 98 (5): 71-102.

Ross, M.L. (1999). The political economy of the resource curse. *World Politics* 51: 297-322.

Ross, M.L. (2001). Does oil hinder democracy? *World Politics* 53: 325-361.

Roubini, N. and X. Sala-i-Martin (1992). Financial repression and economic growth. *Journal of Development Economics* 39: 5-30.

Sachs, J.D. (2003). Institutions don't rule: direct effects of geography on per capita income. NBER Working Paper, No. 9490.

Sachs, J.D. and A.M. Warner (1995a). Natural resource abundance and economic growth. NBER Working Paper, No. 5398.

Sachs, J.D. and A.M. Warner (1995b). Economic convergence and economic policies. NBER Working Paper, No. 5039.

Sachs, J.D. and A.M. Warner (1997). Natural resource abundance and economic growth. Center for International Development and Harvard Institute for International Development, mimeo.

Sachs, J.D. and A.M. Warner (1999). The big push, natural resource booms and growth. *Journal of Development Economics* 59: 43-76.

Sachs, J.D. and A.M. Warner (2001). Natural resources and economic development: the curse of natural resources. *European Economic Review* 45: 827-838.

Sala-i-Martin, X. and A. Subramanian (2003). Addressing the natural resource curse: an illustration from Nigeria. NBER Working Paper, No. 9804.

Sala-i-Martin, X., G. Doppelhofer, and R. Miller (2004). Determinants of long-term growth: a Bayesian Averaging of Classical Estimates (BACE) approach. *American Economic Review* 45: 827-838

Schedvin, C.B. (1990). Staples and regions of Pax Britannica. *Economic History Review* 43 (4): 533-559.

Sokoloff, K.L. and S.L. Engerman (2000). Institutions, factor endowments and paths of development in the New World. *Journal of Economic Perspectives* 14: 217-232.

Sonntag-O'Brien, V. and E. Usher (2004a). Financing options for renewable energy, *Environmental Finance* (Renewables Finance Special Issue) May 2004.

Sonntag-O'Brien, V. and E. Usher (2004b). Mobilising finance for renewable energy. Thematic background paper for the International Conference for Renewable Energies, Bonn, available at http://www.renewables2004.de/pdf/tbd/TBP05-financing.pdf.

Southey, C. (1978). The staples thesis, common property and homesteading. *Canadian Journal of Economics* 11 (3): 547-559.

Stijns, J.-P.C. (2003). An empirical test of the Dutch disease hypothesis using a gravity model of trade. Northeastern University, mimeo.

Stijns, J.-P.C. (2005). Natural resource abundance and economic growth revisited. *Resources Policy* 30: 107-130.

Stijns, J.-P.C. (2006). Natural resource abundance and human capital accumulation. *World Development* 34: 1060-1083.

Suits, D.B. (1957). Use of dummy variables in regression equations. *Journal of the American Statistical Association* 52 (280): 548-551.

Tadesse, S. (2002). Financial architecture and economic performance: international evidence. *Journal of Financial Intermediation* 11: 429-454.

Tornell, A. and P.R. Lane (1999). The voracity effect. *American Economic Review* 89: 22-46.

Torvik, R., 2002. Natural resources, rent seeking and welfare. *Journal of Development Economics* 67: 455-470.

Turner, F.J. (1986). *The frontier in American history.* Tucson, AZ: University of Arizona Press.

UNEP (2004). Financial risk management instruments for renewable energy projects. United Nations Environment Programme/ Sustainable Energy Finance Initiative.

UNEP FI (2004). Renewable energy. United Nations Environment Programme Finance Initiative Climate Change Working Group, CEO Briefing (June 2004).

UNU/ WIDER (2007). World income inequality database. Version 2.0b, May 2007.

Waites, B. (1999). *Europe and the Third World: From colonisation to decolonisation c. 1500-1998.* London: Macmillan.

Watkins, M.H. (1963). A staple theory of economic growth. *Canadian Journal of Economics and Political Science/ Revue Canadienne d'Economie et de Science Politique* 29 (2): 141-158.

Webb, W.P. (1964). *The Great Frontier.* Lincoln, NE: University of Nebraska Press.

Wittfogel, K.A. (1957). *Oriental despotism: A comparative study of total power.* New Haven, CT: Yale University Press.

World Bank (1997). Expanding the measure of wealth: indicators of environmentally sustainable development. Environmentally Sustainable Development Studies and Monographs Series, No. 17.

World Bank (1999). *Energy and development report.* Washington, D.C.: IBRD/ World Bank.

World Bank (2002). *Financing for sustainable development.* Washington, D.C.: IBRD/ World Bank.

World Bank (2003). Power for development: A review of the World Bank Group's experience with private participation in the electricity sector. Operations Evaluation Department, Washington, D.C.: IBRD/ World Bank.

World Bank (2005). *Where is the wealth of nations? Measuring capital for the XXI century.* Washington, D.C.: IBRD/ World Bank.

Wright, G. and J. Czelusta (2004). Why economies slow: the myth of the resource curse. *Challenge: The Magazine of Economic Affairs* 47: 6-38.

Young, C. (1994). *The African colonial state in comparative perspective.* New Haven, CT: Yale University Press.

Zalik, A. (2004). The Niger Delta: "petro violence" and "Partnership Development". *Review of African Political Economy* 101: 401-424.

# Curriculum Vitae

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| 1983 – 1987 | Primary school, Mettmenstetten |
| 1987 – 1988 | Primary school, Croglio |
| 1988 – 1992 | Middle school, Bedigliora |
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| 1996 – 2001 | lic. phil. I (Master of Arts) – Studies in Political Science (Major), Economics (1st Minor) and Russian Literature (2nd Minor) at the University of Zurich |
| 2000 | Exchange semester at the University of Geneva and the Graduate Institute of International Studies |
| 2002 | Post-graduate intern with UBS AG in Zurich |
| 2002 – 2003 | Marketing Consultant with Ernst & Young Ltd. in Moscow |
| 2004 – 2007 | Doctoral studies in economics at the University of Zurich and research assistant at ETH Zurich |